Telecommunications and Networking Systems Operation

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ASSESSMENT OF COMMERCIAL SATELLITE COMMUNICATIONS INITIATIVE (CSCI) STUDIES

FINAL

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N. Smith, W. Kearns, P. Chapell

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This report summarizes the fixed and mobile satellite services (FSS, MSS) as studied by three contractors: COMSAT, Hughes, and Space Systems/LORAL. Each contractor developed a commercial satellite communications initiative (CSCI) architecture based on the requirements provided them from DoD's Integrated Communications Data Base (ICDB). An implementation plan; recommending an acquisition, transition, logistics, and host nation approval plan; was developed according to each contractor's recommended architecture. In addition, this report summarizes the demonstrations conducted by each contractor and the vulnerabilities inherent in using commercial satellites. This summary information is provided as the foundation for the section on the Government's assessment and critique of the CSCI study which emphasizes the highlights and remaining uncertainties from this program.

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Asynchronous Transfer Mode (ATM), C-band, Compact User Pulled Imagery Dissemination (CUPID), Fixed Satellite Service (FSS), General Purpose Requirements, Geosynchronous Earth Orbit (GEO), Host Nation Approval, Ku-band, L-band, Low Earth Orbit (LEO), Mid-Earth Orbit (MEO), Mobile Satellite Service (MSS), transportable gateways, Very Small Aperture Terminal (VSAT), X-band.

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EXECUTIVE SUMMARY

The Commercial Satellite Communications Initiative (CSCI) program began when the White House announced approval in 1991 of new U.S. Commercial Space Policy Guidelines aimed at expanding private investment in space. The House Appropriations committee (HAC) identified funds to contract with commercial satellite communications corporations. Advances in commercial communications systems and the availability of increased capacity for surge requirements were to be aggressively pursued by the Department of Defense (DoD). These contracts were to study the long-term communications needs of DoD and to determine to what degree and how those needs could be met by projected commercial systems.

Space Systems/LORAL was contracted to develop implementable solutions to satisfy the Department's Mobile Satellite Service (MSS) requirements. This service is provided between ships, aircraft, or land mobile terminals and other mobile users or fixed users on land.

Hughes was contracted to develop implementable solutions to satisfy the Department's Fixed Satellite Service (FSS) requirements, which includes fixed or transportable terminals. Transportable terminals are required to communicate while stationary, but not during transportation.

COMSAT was contracted to develop implementable solutions to satisfy both FSS and MSS requirements as an integrated architecture. This contract developed seamless interoperability concepts between the two service types (FSS and MSS).

A detailed DoD communication requirements document derived from the Integrated SATCOM Database (ISDB) and a list of current leases were provided to each contractor. This document defined worldwide peacetime, contingency, and on-call requirements divided into General Purpose (GP) and Core communications service categories. GP requirements are defined as having no anti-jam protection or relaxed low probability of intercept/low probability of deception (LPI/LPD) requirements. Core requirements are defined as having different levels of anti-jam (AJ) protection requirement and/or an LPI/LPD requirement. AJ protection requires countermeasures directed against a range of threats - starting from a nuisance, low power level and escalating to a strategic, very high power level. LPI/LPD is specified according to the degree of covertness and detectability of a terminal measured from the emitter source to the receiver sink. Extremely robust strategic and tactical C3 requirements satisfied by MILSTAR were not included in this study.

The purpose of each contract was to develop implementable solutions for using commercial satellite capabilities to satisfy GP and Core requirements without undue risks to mission completion, excessive added costs, or excessive technical uncertainties. Specific goals were to use emerging new technologies and to assess evolving commercial systems capabilities to design an innovative commercial system. Commercial systems were assessed to objectively and thoroughly size the capability of existing FSS and MSS services as well as new services (DBSS and RDSS) for warfighting. Alternative designs would be assessed in terms of requirements satisfaction, network operations, DoD control, and cost.

Contractors provided a detailed commercial SATCOM architecture, concept of network operations, and a control concept. These results were the baseline for development of an implementation plan. Features from the contractors' architectures were integrated by the Government into an overall commercial satellite communication architecture. Chapter 5 describes the integrated architecture.

The contractors' systems engineering analysis concluded that tactical and strategic general purpose requirements and a select few core requirements (those not requiring anti-jam countermeasures and moderate LPI/LPD requirements) could be supported. Of the 1 Gbps FSS requirements, the range satisfied by the contractors' architectures was from 690 to 763 Mbps. Of the 50 Mbps MSS requirements, 16.5 to 36.5 Mbps were satisfied by the contractors' proposed architectures.

A majority of core requirements are not supportable without unreasonable cost increase. Some solutions are technically possible, but they are not robust in the sense that small changes in assumed threat levels will degrade performance dramatically. More robust performance with increases in threat levels will require operation of commercial satellites in a very inefficient mode with sacrifices in bandwidth utilization and data rate throughput. More costly modifications to incorporate military satellite features in commercial satellites were beyond the scope of the study.

This report summarizes the findings of the architecture development, engineering studies, task orders, and demonstrations.

FSS and MSS Highlights:

- A commercial dedicated private DoD network concept is sound and needs to be pursued.
- Commercial satellites are capable of supporting all GP requirements but only a very limited set of Core requirements with respect to technical feasibility.
- Some FSS low data rate circuits can easily be supported by a far-term MSS architecture at lower cost.
- Some emerging high data rate MSS circuits can be more easily supported on FSS today.
- The positioning of special Ku-band steerable spot beams requires leasing four or five transponders to obtain the steering rights, but DoD lacks a sufficient number of requirements to justify associated costs.
- Large gateway terminals can be used to interface commercial and military traffic and to interface between MSS and FSS.
- Volume discount pricing is a cost effective lease strategy for MSS. Discounts are available with centralized billing practices.
- Host Nation Approval will vary depending on the country but can be a challenge in underdeveloped nations.
- Remote control, automatic switching, and redundant small terminals will reduce the need for additional personnel in a commercial private network.
- Commercial network control can be integrated with DSCS operational control using the same organizational levels.
- Spacecraft control must be under the satellite provider's control.
- Coverage to polar regions is not currently available, but future LEO systems promise to have polar coverage.
- The recommended architectures are flexible enough to integrate future MEO/LEO systems.

Promising new technologies some of which were demonstrated include:

- Asynchronous Tranfer Mode (ATM) over satellite
- Compact User Pulled Imagery Dissemination (CUPID) to remote users via satellite
- Code Division Multiple Access (CDMA)
- Seamless Defense Information Systems Network (DISN) Interface for access via satellite

- Low earth orbit (LEO) personal communication systems (PCS) with handheld terminals

- Internetwork (Teleport) gateways consisting of colocated commercial and military satellite communications terminals.

Implementation of a fully operational DoD dedicated private network, as described in the architectures, is several years away and depends on critical decision milestones involving future DoD satellite communications needs. In the near-term, key architectural concepts for the space, terminals, and control segments can be implemented operationally and evaluated as a pilot network. Starting with a pilot network is the best way for reducing risks and providing feedback for service providers and decision makers.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF CSCI

In 1991, the White House approved a new U.S. Commercial Space Policy Guideline aimed at expanding private investment in space, which began the Commercial Satellite Communications Initiative (CSCI) program. The House Appropriations Committee (HAC) added $15 million above the budget request to fund an initiative by the Assistant Secretary of Defense for C^3I. The HAC cited the advances in commercial satellite technology and charged the DoD to aggressively pursue an expanded role for commercial satellites. These funds were for three to five contracts with corporations with expertise in commercial satellite communications to study the long-term communications needs of DoD and to determine to what degree and how those needs could be met by projected commercial systems.

On July 13, 1992, contracts were awarded to COMSAT, Hughes, and Space Systems/LORAL. Two contractors (COMSAT and Hughes) were chosen to develop Fixed Satellite Service (FSS) architectures and study special engineering tasks, while two contractors (COMSAT and Space Systems/LORAL) were chosen to develop Mobile Satellite Service (MSS) architectures and study additional special engineering tasks. The FSS and MSS designations are defined in accordance with the ITU convention. The role of the contractors is shown in Figure 1-1.

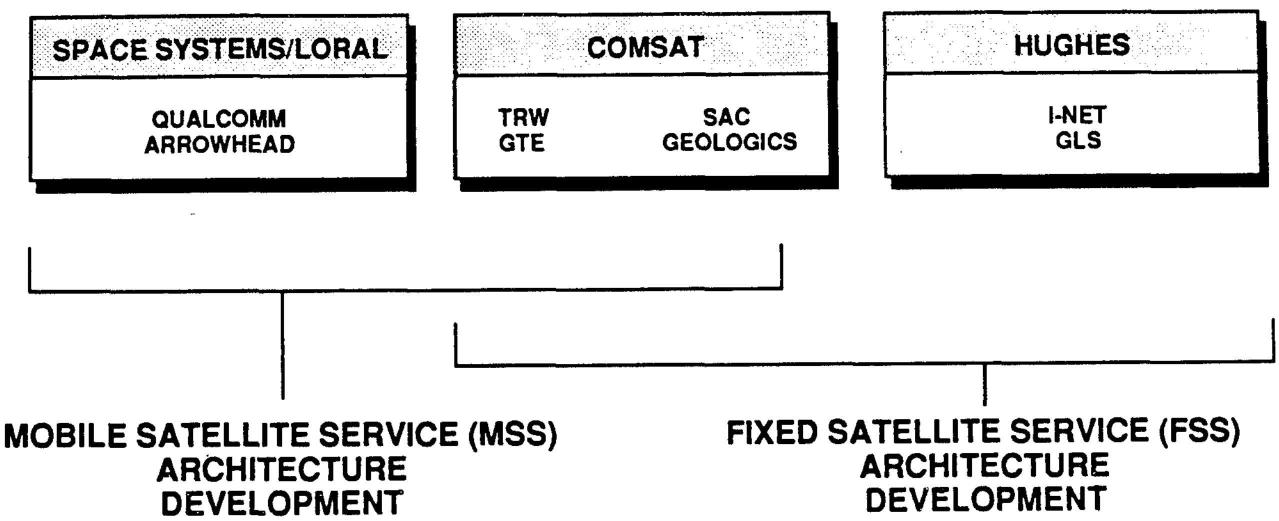


Figure 1-1. CSCI Contractors

Hughes studied DoD's FSS requirements, which include communications using fixed and transportable terminals. Transportable terminals are required to communicate while stationary, but not during movement or transportation. The Hughes contractor team included I-NET and GLS.

Space Systems/LORAL was contracted to study DoD's MSS requirements. This service is provided between ships, aircraft, or land mobile terminals and other mobile or fixed users. The Space Systems/LORAL team included Qualcomm and Arrowhead.

COMSAT was contracted to analyze both FSS and MSS requirements as an integrated architecture. The COMSAT team for the integrated FSS and MSS architecture design included TRW, GTE, SAC, and Geologics.

By January 1993, optional task orders and demonstrations were funded. The total funds awarded were $5345 K to COMSAT, $2707 K to Hughes, and $2217 K to LORAL. This report summarizes the findings of the architecture development, engineering studies, task orders, and demonstrations.

1.2 PURPOSE OF PROGRAM

This CSCI program was funded to determine specific, implementable solutions for using commercial satellite capabilities to satisfy DoD general purpose and supportable core requirements. To achieve this purpose several goals were established:

- Develop innovative commercial system architectures
- Objectively and thoroughly size the capabilities of commercial FSS and mobile satellite systems
- Assess the commercial systems capability to support evolving military requirements
- Assess the designs in terms of network operations, DoD control, and cost and analyze the use of FSS, MSS, DBSS, and RDSS for warfighting
- Apply new and emerging technologies.

The type of service (either FSS or MSS) is distinguished by the type of platform upon which a terminal will reside. FSS will reside on fixed or transportable platforms that are stationary during operation. MSS will reside on mobile platforms such as vehicles, aircraft, and shipboard terminals that can be in motion during operation. The purpose in designing the FSS

and MSS network is to meet operational support requirements, reduce DoD telecommunications costs, enhance the diversity of the DoD satellite communications, take advantage of the newest commercial services, and provide pre-planned surge capacity for crisis and low intensity conflict.

1.3 SCOPE OF STUDY

Each contractor was required to develop a detailed commercial SATCOM architecture and supporting concept of network operations and control based upon the 1997 communications requirements. These requirements are contained in the DoD Integrated SATCOM Database (ISDB) and were furnished to the contractors. A list of current commercial satellite circuit leases was also supplied.

In this document, worldwide peacetime, contingency, and on-call requirements were defined and categorized into General Purpose (GP) and Core networks as shown by Figure 1-2. GP networks are defined as having no anti-jam protection or relaxed low probability of intercept/low probability of deception (LPI/LPD) requirements. Core networks are defined as requiring anti-jam or LPI/LPD protection. Hard Core networks have stringent survivability requirements and are beyond the scope of commercial SATCOM capabilities; thus, these requirements, supported by MILSTAR, were not provided to the contractors.

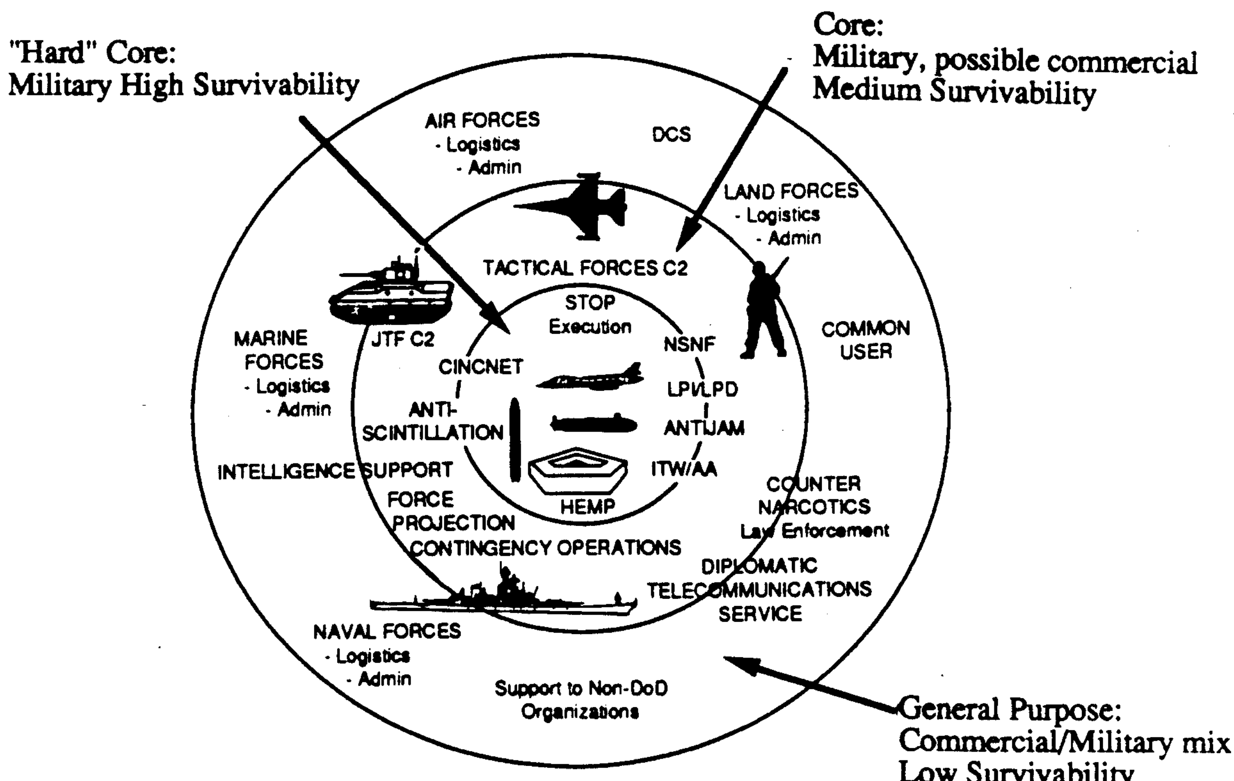


Figure 1-2. DoD SATCOM Requirements

The total requirements provided to the contractors for GP and core are approximately 1 Gbps for FSS and 50 Mbps for MSS. Figure 1-3 depicts the breakdown of these requirements among the seven Joint Staff-defined DoD missions.

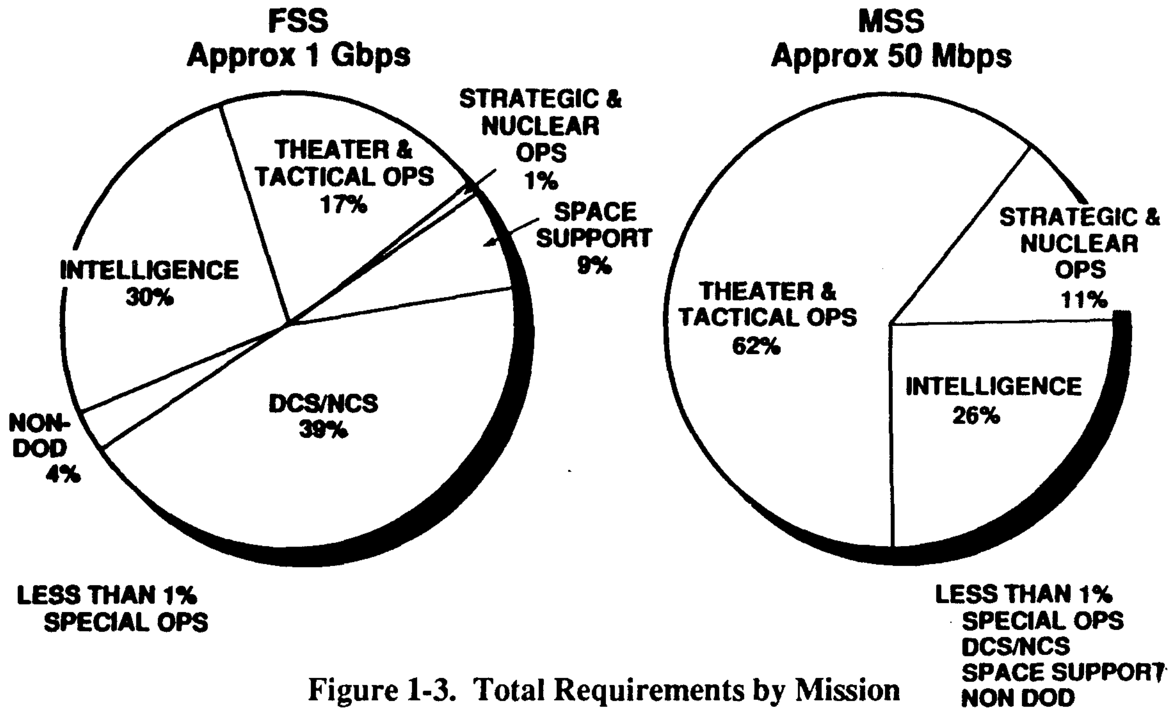


Figure 1-3. Total Requirements by Mission

Based on each contractor's initial findings and results, an implementation plan was developed that included Host Nation Approval, acquisition, transition, and logistics strategies and an estimate of 10-year life cycle cost. These products were evaluated and high payoff recommendations were integrated into a capabilities architecture to address requirements identified as supportable on commercial satellites. The complete package of reports to be delivered under the CSCI contract is shown in Figure 1-4.

1.4 ORGANIZATION OF REPORT

This document is organized to report results of each contractor in chapters 2 through 4. Within each chapter, a synopsis of the contractor's recommended architecture and associated implementation strategy is presented. Chapter 5 presents an integrated Government architecture developed from contractor's recommendations. Chapter 6 summarizes the vulnerabilities of commercial SATCOM. New technologies and innovative configurations proposed by each contractor are presented in chapter 7. Chapter 8 presents Government comments on the contractors' work. Chapter 9 presents a summary of all recommendations and conclusions and potential follow-on efforts.

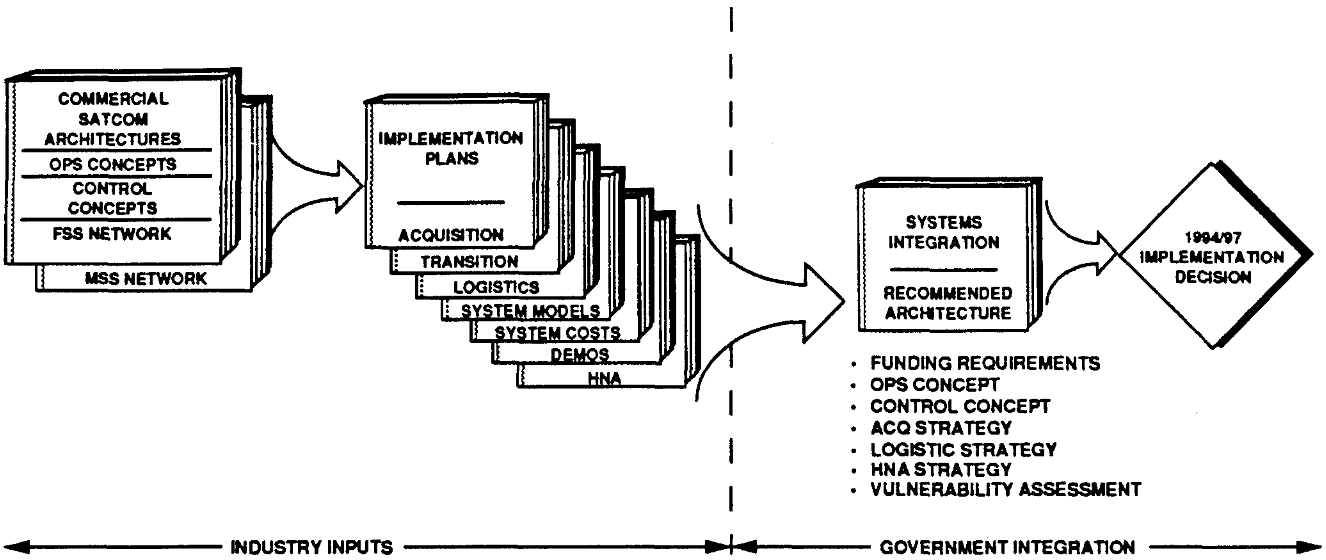


Figure 1-4. Products to be Delivered

CHAPTER 2
COMSAT RESULTS

2.1 COMSAT RECOMMENDED ARCHITECTURE

COMSAT's approach to developing their FSS architecture was to meet the technical requirements of the Joint Staff defined seven user missions with satellites from multiple operators, using a detailed analysis of traffic requirements and a strong emphasis on minimizing cost. COMSAT's assumptions in developing this architecture were that no major modifications were to be made to the spacecraft or earth terminals and that a multiple vendor solution was preferred.

COMSAT's approach to developing their MSS architecture was to use existing (INMARSAT) or newer satellite systems funded for development in the near term. Personal communications services (PCS) systems augment initial capabilities in the far term. The COMSAT architecture will use PCS systems that are implemented to satisfy low data rate land, sea and air requirements.

COMSAT's architecture addresses all MSS circuit requirements having a data rate of 32 kbps or less by using mobile systems. A sub-architecture was used to satisfy MSS requirements of 64 kbps and higher by using FSS (i.e., C- or Ku-band) systems.

COMSAT's integrated architecture, incorporating both FSS and MSS components, supports 690 Mbps for FSS and 36.5 Mbps for MSS. A majority of core requirements remained unsatisfied. Only those core networks that required nuisance (i.e., unintentional) jamming protection, LPI/LPD level 4 protection, or had a zero stressed data rate were satisfied by this architecture. Details of COMSAT's studies are included in their final report [Ref. 2]. The percentage of requirements satisfied is shown in Figure 2-1.

2.1.1 Space Segment

COMSAT performed a rigorous analysis of requirements and developed a rule-based satellite transponder loading model, which was used to determine space segment capacity needs. The model was technically sound but has not been independently validated by the Government. In some instances, the specification of a multi-vendor satellite space segment solution precluded optimization of capacity allocation by the model.

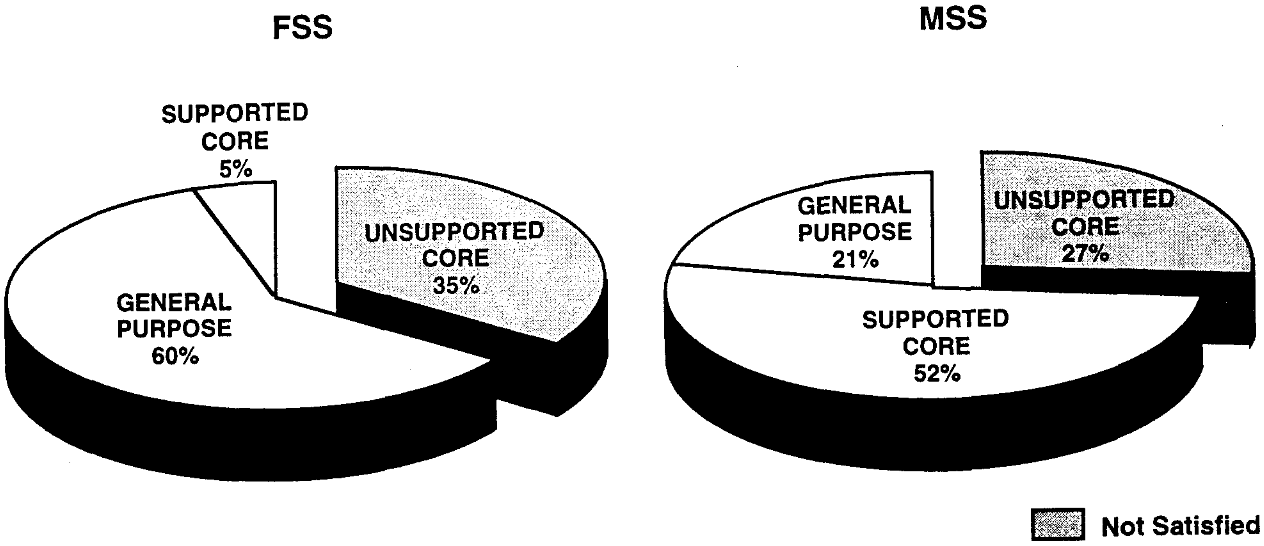


Figure 2-1. Requirements Satisfaction by COMSAT's Integrated Architecture

COMSAT's FSS multivendor space segment uses capacity from the following nine satellites: INTELSAT (4), PANAMSAT (2), Aurora (1), a Eutelsat (1), and Gstar (1). This satellite system is arranged such that two satellites cover each region in the West Pacific, East Pacific, West Atlantic, and East Atlantic areas with one satellite covering the Indian Ocean area. The total capacity needed for FSS general purpose and the supported core networks is 22 C-band and 17 Ku-band transponders.

The space segment COMSAT recommended for MSS is INMARSAT and Odyssey. INMARSAT was chosen because it is an existing, mature system with known performance and worldwide mid-latitude coverage. Its disadvantages includes a limited bandwidth and limited medium data rates (i.e., 64 kbps or less support). The Low Earth Orbit (LEO) Odyssey L-band service was chosen because it will support handheld and low cost terminals and is representative of the PCS systems to be available at the end of the decade. Because the system is under development, operational capabilities and performance are still general or undefined.

Additional maritime capacity and unique services such as data rates greater than 64 kbps are satisfied by INTELSAT C-band global beams and Ku-band steerable spot beams on INTELSAT VII satellites. At C-band, INTELSAT VII can support up to 1.544 Mbps in the

global beam and up to 3.088 Mbps in the hemispheric and zone beams, given the proper sized antenna for the shore and shipborne terminals. Where possible, COMSAT recommends the use of cross-strapped transponders to support some maritime traffic such as C-band hemispherical beam to Ku-band spot beam, which can support the shore to ship traffic, and Ku-band spot beam to C-band hemispherical beam, which can support ship to shore traffic. An example of COMSAT's recommended satellite constellation is shown in Figure 2-2.

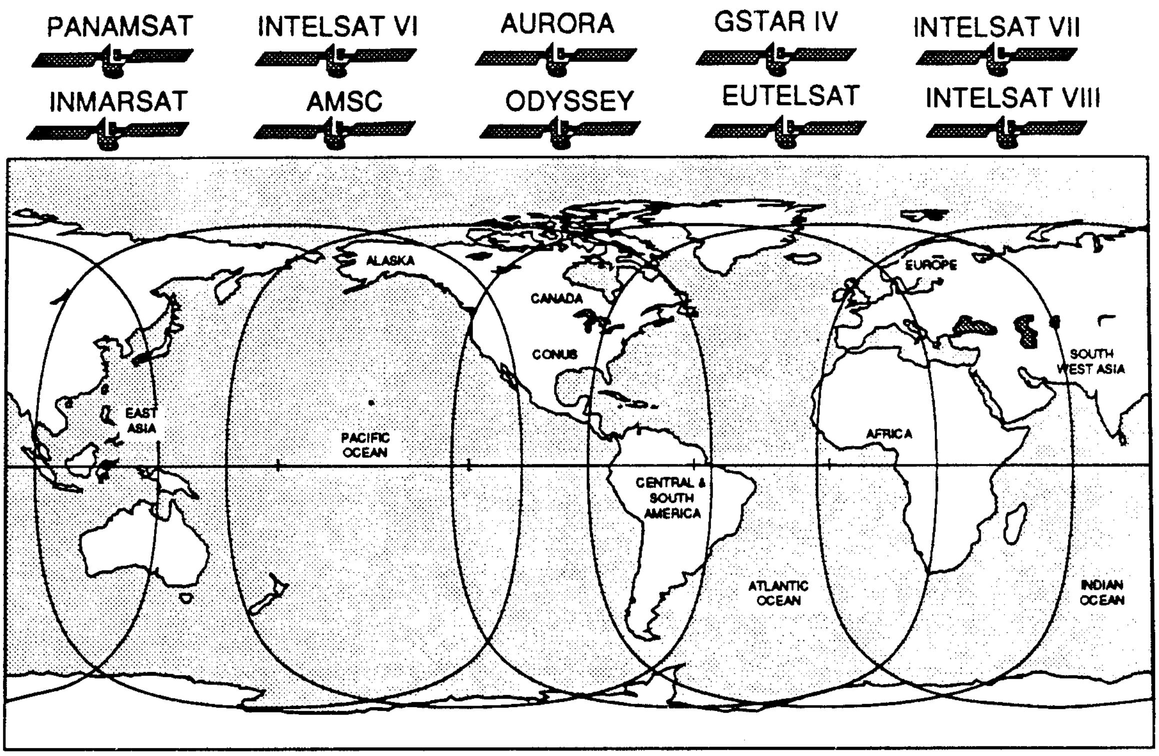


Figure 2-2. Multivendor Space Segment

A drawback to the use of C-band on mobile platforms is the potential for interference with terrestrial communications systems that operate in the same frequency band. This approach needs further investigation on a case by case basis because there may be no other near-term solution for meeting high data rate mobile communications.

2.1.2 Earth Terminal Segment

The earth terminal types were selected by COMSAT to provide a multivendor capability and to operate in different environments. At each location, COMSAT's architecture uses either very small (up to 1.8 m antennas), medium (3.7 to 6.1 m antennas), or large (9.0 to 15.2 m antennas) terminals depending on required throughput.

The total number of terminals needed to satisfy general purpose requirements was estimated at 1469. FSS accounted for 556 terminals, while MSS accounted for 913 terminals of which 500 were for land and PCS operations. A detailed terminal count is shown in Table 2-1.

Table 2-1. Overall FSS and MSS Terminal Count

FSS		MSS	
TYPE	**QUANTITY**	**TYPE**	**QUANTITY**
L-BAND		**L-BAND**	
Standard-M	28	MAR-B (1 channel)	150
Standard-B (INMARSAT)	49	MAR-B (4 channels)	50
C-BAND		AERO HI (2 channels)	75
Standard-B (INTELSAT)	8	AERO HI (6 channels)	75
F0	67	Land M (1 channel)	200
F1	35	PCS (1 channel)	300
F2	33	**C-BAND**	
F3	1	Aero (3 Mbps)	3
VSAT-C	91		
KU-BAND		**C-Band and KU-BAND**	
E0	73	MAR (MDR)	60
E1	46		
E2	6		
4.6 meter Trans	5		
2.4 meter Trans	44		
VSAT-K	70		

VSAT were assigned to a location based on data rate and distance to another terminal. COMSAT's clustering concept reduced costs by providing a larger terminal with landline access to serve regional users instead of providing each user a separate customer premise VSAT. In CONUS, any user location beyond 400 km to another terminal and with a data rate less than 19.2 kbps received a VSAT as opposed to a terrestrial leased line. Outside CONUS any user location

beyond 100 km and less than 2.4 kbps received a VSAT. In some OCONUS cases, clustering could present a risk due to inability to directly control terrestrial tails beyond U.S. facilities.

The earth terminals for the MSS architecture are divided into three service types: maritime, airborne, and land. Maritime service is supported by a combination of INMARSAT Standard B and dual band (i.e., C- and Ku-band) terminals, totaling 260 for peacetime, on call, and contingency operations. Airborne service is supported by a total of 153 INMARSAT Aero High and C-band terminals. C-band aeronautical terminals are needed for high data rate mobile users because there is insufficient capacity at L-band. This is an area of risk because of potential interference with terrestrial C-band relay stations or satellite terminals. Land service is supported by a mix of INMARSAT Standard M and PCS terminals. An example of the various types of earth terminals used and the interface between gateways is shown in Figure 2-3.

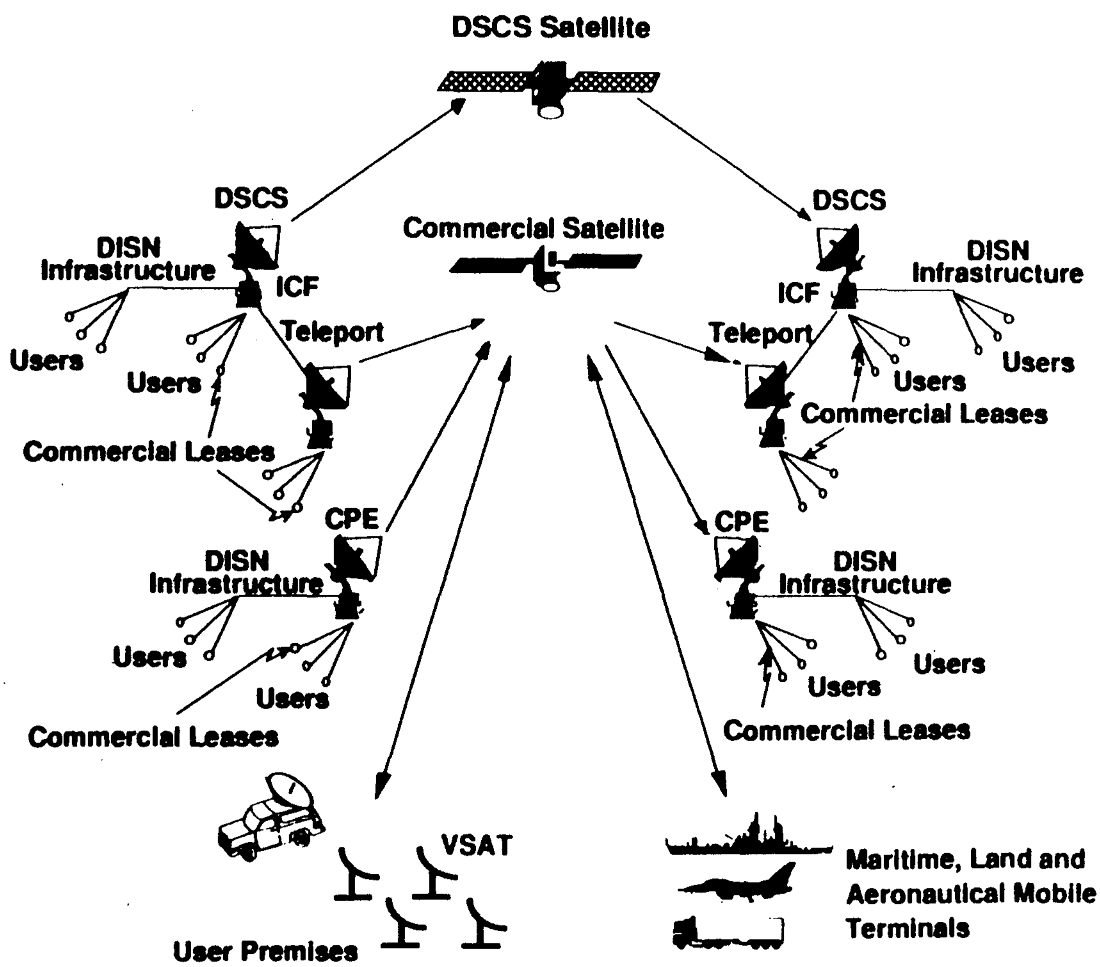


Figure 2-3. COMSAT's Integrated FSS and MSS Architecture

Gateways linking MSS users and DISN are identified by COMSAT for L-band and C/Ku-band operations in each major coverage region. Primary L-band gateways are at Santa Paula, CA (POR); Washington, DC (CONUS); Southbury, CT (ADR); and Anatolia, Turkey (IOR). Primary C/Ku-band gateways are in Sunnyvale, CA (POR); Norfolk, VA (ADR), and Croughton, UK (IOR).

2.1.3 Control Segment

The operations and network control performed by DoD are bandwidth allocation, terminal configuration, network performance, accounting and billing, and security management. These control functions benefit by the use of automated network management systems to streamline operations and cost. Additional streamlining is achieved by centralizing most of the network management functions for commercial and military SATCOM into a single facility. Thus, the proposed automated, remote monitoring and control is structured in a three level hierarchy mirroring the current military control system.

At level III for the military system, the Network Control Terminal (NCT) will monitor a satellite and feeds the information to the Defense Integrated Management System (DIMS). For the FSS system, the Network Monitoring System (NMS) will monitor an FSS satellite and pass the information to the FSS Net Control Subsystem (NCS). For the MSS system, the Technical Control Office (TCO), collocated with the Land Earth Station (LES), will provide automated functions such as Demand Assigned Multiple Access (DAMA) and manual functions such as multipoint-to-multipoint networks. This level will implement the control required to maintain network integrity and service quality to the users. In addition, this level will provide two areas of support: maintenance and logistics operations, and billing and accounting operations.

At level II the DIMS and NCS will be integrated at the Area Communications and Operations Centers/Network Monitoring System (ACOC/NMC), which is also responsible for DISN integrated network management and control. This level will be responsible for configuration, performance, fault, access and accounting management, and security of FSS network resources and is planned to provide operational direction and oversight capability to commanders and communications network managers.

At level I the ACOC/NMCs will be integrated at the Defense Information Systems Agency/Network Operations Center (DISA/NOC). Streamlined operations and reduced cost will be achieved by centralizing the network management functions of Joint Operations Support

Center/Technical Control and Operations Center (JOSC/TCOC) and FSS/NCS facility. This level will be responsible for worldwide operational management, planning service requirements, and allocating space segments in accordance with Joint Communications Satellite Center (JCSC) direction. The JCSC validates user requirements, apportions and adjudicates space segment resources, and provides guidance and direction to the network operations center and network management centers. The planned integrated operations and network control for military and commercial systems is shown in Figure 2-4.

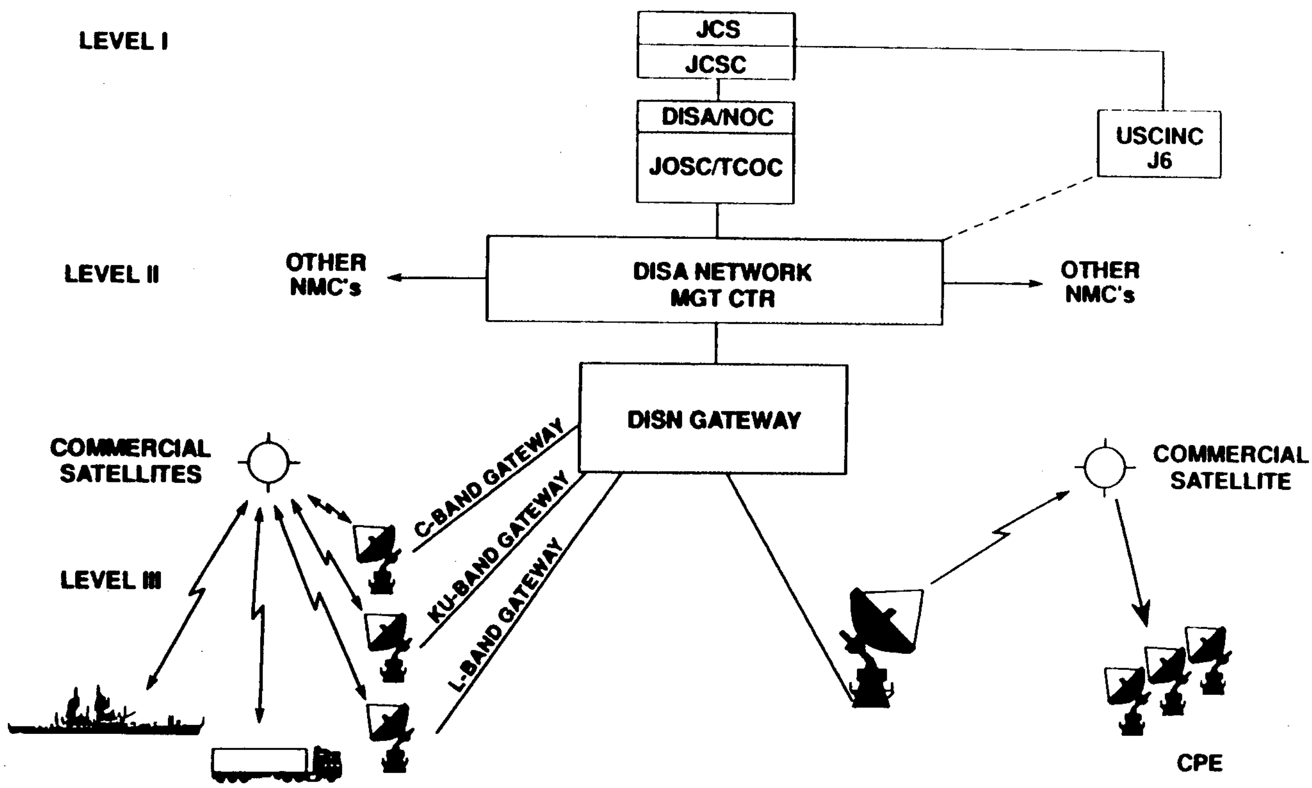


Figure 2-4. COMSAT's Operations and Network Control Segment

2.2 STRATEGIES FOR IMPLEMENTATION OF ARCHITECTURE

The interrelationship of Host Nation Approval (HNA) negotiating, logistics, acquisition, and transition plans is shown in Figure 2-5. COMSAT's implementation plan is based on a time phased implementation of terminals and user networks in an ocean region. The space segment

implementation must begin as soon as possible with an early commitment to leasing resources or at least purchasing the first right of refusal to guarantee availability of transponder resources. COMSAT's strategy for implementation of MSS is to transition military users to currently available commercial services and acquire new services (e.g., PCS) as they become available and as dictated by need.

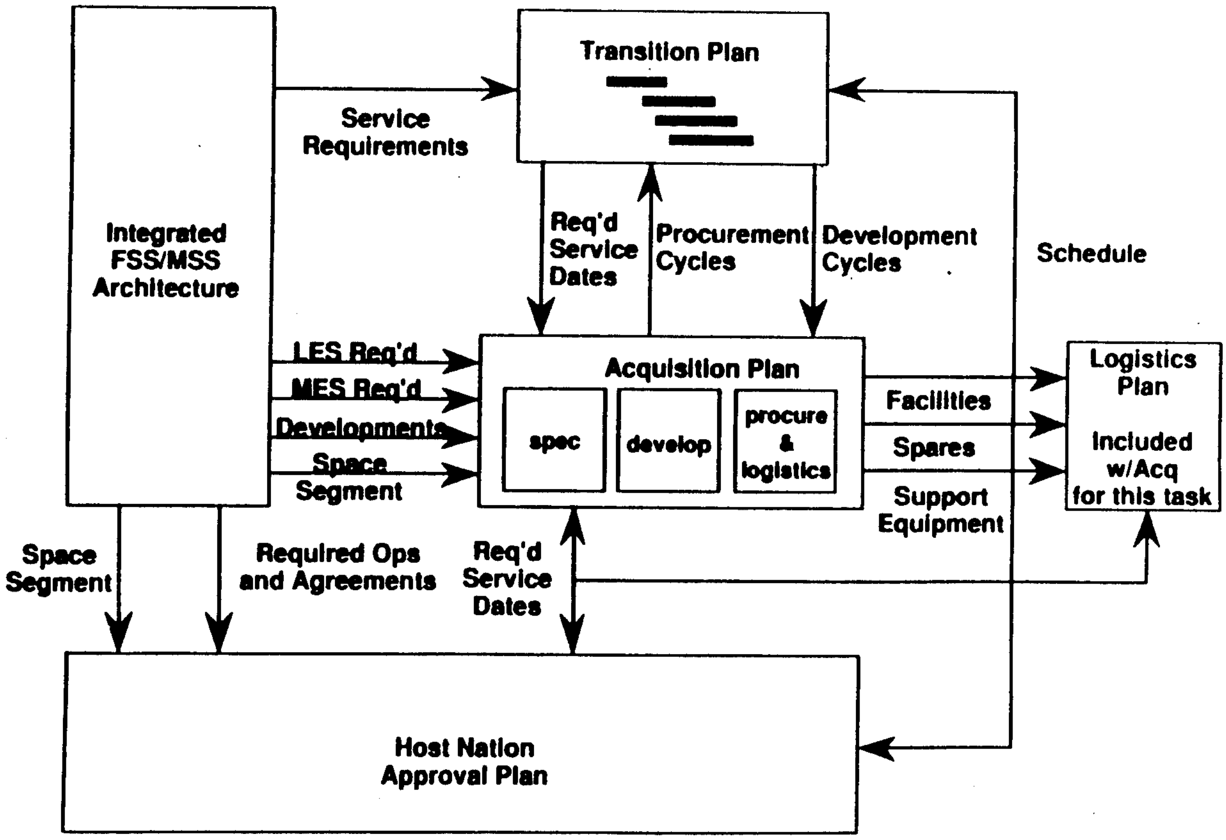


Figure 2-5. Implementation Planning Relationships

2.2.1 Host Nation Approval Negotiations

Deregulation, privatization, and liberalization of the telecommunication industry is changing the negotiating environment throughout the developed world. Deregulation is generally opposed in developing countries, but the increasing cost of providing new products and services is causing developing countries to be more open to new telecommunications ideas. This new global environment and steadily increasing use of digital communications is promoting

worldwide interoperability and international standards. No treaty was identified that specifically prohibits U.S. Government operation of CSCI earth stations in any potential host nation.

Points of contact for opening CSCI negotiations with several countries are provided in COMSAT's Host Nation Approval Negotiating Plan. The negotiations should be conducted between a U.S. commercial service integrator and foreign telecommunications entities. The fact that the CSCI contractor is implementing a network to support the U.S. DoD should be treated as usual business. U.S. Government involvement by the Department of State will be only as necessary (depending on the country). The approach to negotiations will vary depending upon the level of development within each country.

2.2.2 Acquisition Plan

Equipment acquisition will be on a time phased schedule for each ocean region based on space segment availability, which will drive the required service dates. Because this plan is modular, it can be implemented in several phases starting with a pilot capability. Full implementation and equipment acquisition depends on critical decision milestones involving future DoD satellite communications needs.

2.2.3 Transition Plan

COMSAT's approach to transition into a fully integrated military and commercial system is to implement communications links according to DoD established priorities and service types. FSS terminals will be colocated with existing military terminals. At user locations lacking FSS terminals, Customer Premise Equipment (CPE), typically a VSAT terminal, will be assigned. Small areas with many newly assigned VSATs will be clustered into one terminal with new leased tail circuits.

For VSAT CPE, site preparation and service transition will be one service region at a time. Terminals, hardware, and software will then be regionally tested, verified, and certified. Network transition and configuration will be managed by adding components to the Network Management System (NMS) database as terminals are certified. A hot cutover will be implemented at a time when traffic utilization is very low.

Transition for point-to-point maritime, aeronautical, and land mobile satellite secure voice and data service can be initiated immediately. INMARSAT conference calls using a

demonstrated shared push-to-talk circuit needs INMARSAT Council approval. The INMARSAT Council approval is required because of equipment modifications to ship terminals (push-to-talk capabilities) and gateways (loop-backs). Users can transition to additional services (e.g., N-ISDN, compressed TV, video conferencing) as the capabilities become available.

For the military overlay, an interconnect facility (ICF) needs to be constructed between the military and commercial gateways. The ICF will link military and commercial gateways at data rates of 1.544 Mbps or higher.

2.2.4 Logistics Plan

To maintain high equipment availability in remote areas lacking a commercial maintenance contractor, all critical components except antennas will be redundant. VSAT terminals are typically unmanned and will have remote control or automatic switchover capabilities to keep the time to restore to a minimum. When necessary, repair technicians will be dispatched from major earth terminals. All other terminals will have on-site personnel for repair and maintenance.

CHAPTER 3
HUGHES RESULTS

3.1 HUGHES RECOMMENDED ARCHITECTURE

Hughes' approach to development of a recommended commercial SATCOM architecture was to rely on commercial-off-the-shelf (COTS) equipment and services, to maximize flexibility for DoD users, and to match Government general purpose requirements to commercial SATCOM capabilities. Flexibility was achieved by using open systems with modular equipment and emphasizing the use of customer premise equipment.

3.1.1 Space Segment

Worldwide loading analyses were conducted by Hughes using standard assumptions and by applying analytical tools and models developed in previous efforts to address similar sets of requirements for commercial customers. The use of standard assumption provided a less rigorous solution than a loading model, but the standard assumptions were adequate. Hughes selected five satellite service regions to support the traffic requirements based on area of coverage and the frequency band.

The five service regions selected are Domestic (U.S.) Ku-band, Atlantic C-band, Atlantic Ku-band, Pacific C-band, and Indian Ocean C-band. Worldwide mid-latitude coverage (i.e., 70°N to 70°S) is provided by selecting these five areas. Overlapping service is provided to areas with a high demand for capacity. INTELSAT VII and Panamsat PAS-3 generation satellites, available in 1995, will provide worldwide coverage.

The requirements satisfied with this FSS architecture total 763 Mbps. However, multihop traffic added 215 Mbps for a total system throughput of 978 Mbps. Total traffic and the percent of multihop traffic in each region are shown in Figure 3-1.

To support DoD requirements, several transponders are necessary in each of the five satellite regions. The Domestic Ku-band region required eight transponders. The Atlantic Ku-band and Indian Ocean C-band regions both required four transponders. The Pacific C-band region required three, while the Atlantic C-band region required two transponders. This transponder count (total of 21) includes allocations for additional requirements such as double

hopped traffic and contingencies (surge in traffic due to crisis or warfighting). In each region, the totals reflect rounding up fractional transponder capacity to the next integer value.

Region	Total Traffic	Multi Hop Traffic	Multi Hop %
Domestic Ku	340.1	32.9	9.7%
Atlantic Ku	136.4	57.8	42.4%
Atlantic C	63.2	26.0	41.1%
Pacific C	82.0	33.2	40.5%
Indian C	141.5	61.9	43.8%
Totals	763.2	211.8	28.3%

Includes all multi-hop, currently leased, and contingency traffic

Figure 3-1. Multi-Hop Traffic Contribution by Region

3.1.2 Earth Terminal Segment

The Hughes FSS architecture uses three categories of earth terminal: VSATs, Trunks and Hubs.

The VSAT terminals are either fixed or transportable and typically have small antennas, low power transmitters, and support relatively few channels. However, these terminals are relatively inexpensive because of volume production. Hughes selected two types of VSATs: a Ku-band terminal with a 2.4-m aperture and a C-band terminal with a 3.8-m antenna diameter. Both terminal types are equipped with 16- to 20-Watt HPAs and support between 4 to 24 links. These VSATs were used in a mesh configuration because requirements for a hubbed VSAT service have not been expressed by DoD users. The cost savings advantages of a hub VSAT network for transaction oriented data and asymmetrical communications were discussed by Hughes.

The Trunk terminal is also fixed or transportable and typically has a medium-sized antenna, a high power transmitter, and supports a relatively small number of high data rate, point-to-point links. Hughes selected a 6.1-m antenna aperture that operates at either C- or Ku-band. It is equipped with 300- to 400-Watt HPA and supports two to five high data rate links.

The Hub terminal is a fixed facility equipped with large antennas, high power transmitters, and capable of supporting many links. Hughes selected an 11-m antenna with a

300- to 400-Watt HPA operating at either C- or Ku-band to support up to 45 links. The various terminal types recommended by Hughes are shown in Table 3-1.

The number and size of earth terminals allocated to a given location were based on its required composite throughput. Locations requiring low data rates (i.e., 0.075 to 1544 kbps) were assigned VSATs. Locations requiring higher data rates (above 8 Mbps) were assigned a Hub terminal. Locations with data rates between the VSAT and Hub size (1.544 to 8.0 Mbps) were assigned Trunk terminals. Links located near each other were aggregated and assigned to the next larger earth terminal (either a Trunk or Hub).

Table 3-1. Hughes Terminal Types

	VSAT		Trunk		Hub	
Antenna diameter, m	2.4	3.8	6.1		11.0	
Frequency band	Ku	C	Ku	C	Ku	C
HPA, W	8 or 16	10 or 20	300	400	300	400
Total data rate, Kbps	0.075 to 1,544	0.075 to 1,544	1,544 to 8,000	1,544 to 8,000	8,000 to 60,000	8,000 to 60,000
Number of Tx carriers	4 to 24	4 to 24	2 to 5	2 to 5	6 to 45	6 to 45

To satisfy all requirements, the Hughes architecture required 31 hub, 65 trunk, and 686 VSAT terminals (782 total terminals) as shown in Table 3-2. This count includes two terminals at each VSAT site to meet nuisance maintenance requirements as specified in the CSCI programs and requirements document. The Hughes concept to mitigate the effects of nuisance level (i.e., unintentional) jamming is to use signal path diversity implemented with two terminals transmitting to separate satellites. Higher level intentional jamming with multiple interferors can defeat this technique.

Gateway stations, to relay traffic between coverage regions or to change frequency bands, were assigned in pairs. The following gateways were recommended for inter-regional relays: Andrews AFB, Maryland; Cape Canaveral, Florida; Landstuhl, Germany; Croughton, UK; H. E. Holt, Australia; Watsonia, Australia; Wahiawa, Hawaii; and Camp Roberts, California. To change operating frequency bands, the following gateways are recommended: Norfolk, Virginia; Patrick AFB, Florida; Fort Allen, Puerto Rico; and Ramstein, Germany. If satellites with

frequency cross strapping capability are used in the architecture (e.g., INTELSAT VII), the latter set of gateways is unnecessary.

Table 3-2. General Purpose Terminal Distribution

	HUB	TRUNK	VSAT	TOTAL
Domestic US Ku	13	34	294	341
Atlantic K	9	10	166	185
Total Ku-Band	22	44	460	526
Atlantic C	5	10	96	111
Pacific C	3	6	114	123
Indian C	1	5	16	22
Total C-Band	9	21	226	256
Total Terminals	**31**	**65**	**686**	**782**

To provide the best combination of power and bandwidth usage, QPSK modulation with rate 1/2 coding was selected for most links. For hub and trunk terminals with more power and antenna gain, a rate 3/4 coding was selected to more efficiently use transponder bandwidth.

3.1.3 Control Segment

The Hughes control segment design is based upon the inherent monitoring and control features of DISN/DOCS facilities with a system structure consistent with the DISN integrated network management concept. A COTS open system control architecture is planned to be implemented for the FSS NCS. Compatibility and interoperability between the FSS NCS and DISN Integrated Network Management and Control System can be achieved through a selection of standard protocol and interfaces. In addition to the interface with DISN, the FSS NCS is also planned to interface with the existing FSS payload management facilities, the DIMS, the DISN terrestrial control orderwire networks, and FSS subnetwork control terminals.

The recommended Hughes control hierarchy provides three levels of network management and control support: FSS Level I Executive Management, FSS Level II SATCOM Network Management and Control, and FSS Level III SATCOM Subnetwork Management and Control.

Executive Management (Level I) will monitor and oversee status of worldwide FSS networks from the DISN Network Monitoring Center located at DISA/NOC, Arlington, VA. It will directly interface to the National Command Authority (NCA) and to Level II FSS NCS.

SATCOM Network Management and Control (Level II) functions as the technical management of FSS resources, which includes day-to-day operations and control of FSS networks, and space segment power, bandwidth, and frequency allocations. Level II NCSs operate from ACOC/DSCS Operations Centers (DSCSOC). Their responsibility is generally management of one satellite including: operational and technical direction to Level III NMCs (via a direct interface), control of all subnetwork control terminals and satellite accesses, status reporting, performance monitoring, link and network configuration control, and satellite configuration, reconstitution and restoral.

SATCOM Subnetwork Management and Control (Level III) functions as direct day-to-day operation and control of FSS earth terminals under the authority and direction of FSS Level II. Three FSS subnetwork control centers, collocated at a selected military earth terminal, will be provided in each area (one each for the hub, trunk, and VSAT terminals).

3.2 STRATEGIES FOR IMPLEMENTATION OF ARCHITECTURE

The Hughes implementation plan was developed with an understanding that commercial SATCOM capabilities and services are to be fully integrated within an overall MILSATCOM architecture. Thus, their strategies reflect the military requirements and operational environment. In addition, Hughes considered the acquisition, transition, logistics, and host nation approval plans as interrelated with the completion and execution of each plan as essential to the successful implementation of a given network.

3.2.1 Host Nation Approval

A multi-step approach was recommended by Hughes to obtain host nation approval for the foreign half circuit of general purpose communications. The approach suggests that commercial SATCOM landing rights be included in all negotiated international treaties. When considering a commercial SATCOM implementation in a foreign country, any existing agreements between the U.S. and that country should be checked to determine whether host nation rights have already been addressed. Commercial SATCOM landing rights, if not already obtained through these prior agreements, should be obtained in the host nation by the

international satellite system operator. An operating agreement, also if not already obtained, should be secured with the host nation for the specific service and the anticipated length of time by one of three approaches. The preferable approach is to permit the international satellite system operator to negotiate the operating rights with the foreign country on behalf of the U.S. Government. The second approach is to use a private company established in the host nation to negotiate and provide the required service. The third approach is to have the U.S. Government directly negotiate the operating rights with the host nation.

Because of the changing environment, Hughes further recommended that the U.S. Government remain current with worldwide telecommunications policies. Countries in regions such as Europe and Latin America are liberalizing these policies at a rapid pace in preparation for the implementation of new global networks. Using one of the aforementioned approaches, negotiating plans for SATCOM service in each country can be developed and implemented. The estimated time to complete negotiations for FSS in various countries is shown on the map in Figure 3-2.

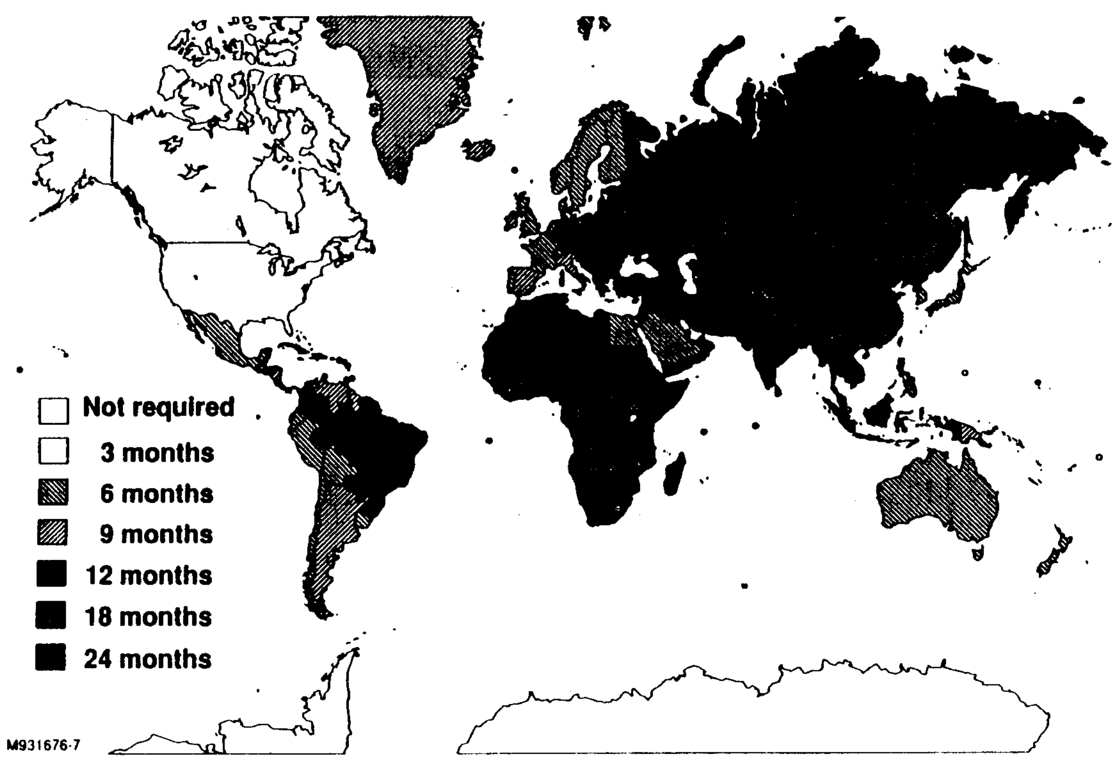


Figure 3-2. Estimated HNA Completion Time for FSS Representative Countries

3.2.2 Acquisition Plan

The Hughes approach to acquisition of all equipment and services would be to perform a market survey with gathered vendor information, develop site configurations on a regional basis, and document plans ready for Government approval. A standardized design could be used for similar sites. Implementation would be on a regional basis with time phased acquisition of equipment and services.

3.2.3 Transition Plan

In keeping with a regional acquisition strategy, transition of MILSATCOM or existing commercial leased circuits would be on a region by region basis starting with smaller networks first. All networks would have dual paths over the existing and new network during the transition (providing seamless operations). Networks, more difficult to transition, will be established as pilot networks to resolve issues such as interfaces, installation procedures, and management before being accepted for full transition. A proposed transition plan is shown in

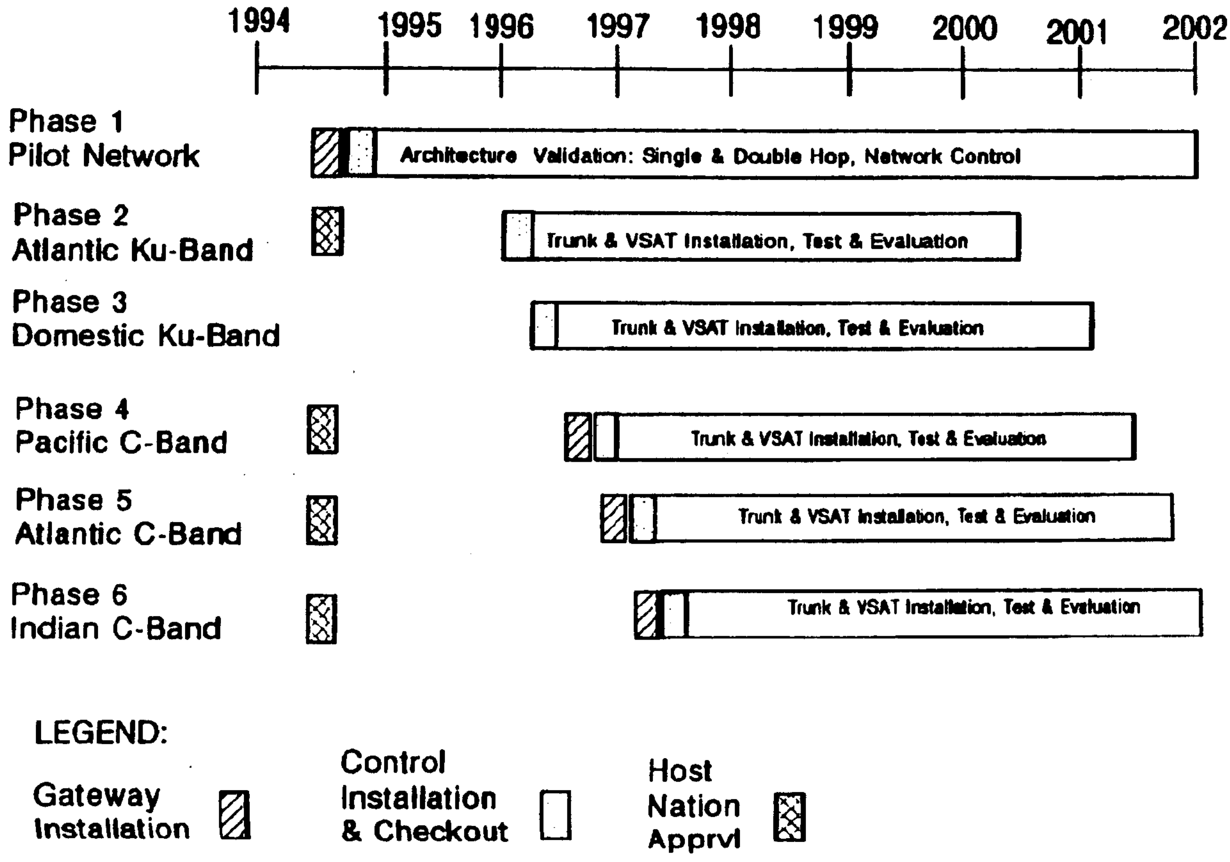


Figure 3-3. FSS Transition Plan

3.2.4 Logistics Plan

The logistics planning is based upon minimum support and maintenance concepts to provide equipment and trained personnel as required. Thus, VSATs are provided with redundant systems that can be remotely reconfigured with regional repair personnel instead of on-site operators and maintenance personnel. Both hub and trunk terminals will be provided two maintenance people per site in addition to the operators.

The logistics plan is based on the use of existing DoD resources to supplement on-site operations and support maintenance for installed CSCI equipment. Hughes estimates that the workload generated by the commercial assets at any network facility is not sufficient to justify dedicated support personnel. At sites where they are available, DoD personnel could provide the required support services as an additional duty. At sites where DoD personnel are unavailable, commercial companies could provide these services on a contract basis.

Depot level repair/resupply of CSCI assets would be performed by the equipment supplier. On-site spares are required to maintain the performance of hub and trunk terminals. VSAT locations are provided fully redundant units to achieve the required circuit availabilities and mean times for restoral in remote areas. With this highly reliable configuration, VSAT spares may be centrally located at regional facilities.

CHAPTER 4
SPACE SYSTEMS/LORAL RESULTS

4.1 SS/LORAL RECOMMENDED ARCHITECTURE

SS/LORAL's approach to developing an MSS architecture was to analyze requirements and threats provided by the Government, characterize all candidate existing and future MSS systems, derive system and network control requirements, define alternative architectures, assess the alternatives performance in satisfying DoD user/mission needs, and estimate the cost of each alternative. The focus of this development effort was to design a future goal architecture using a mix of available MSS systems. A transition plan was developed using INMARSAT as the initial service provider. New MSS systems were added as they became operational until the goal architecture was achieved by approximately the year 2000.

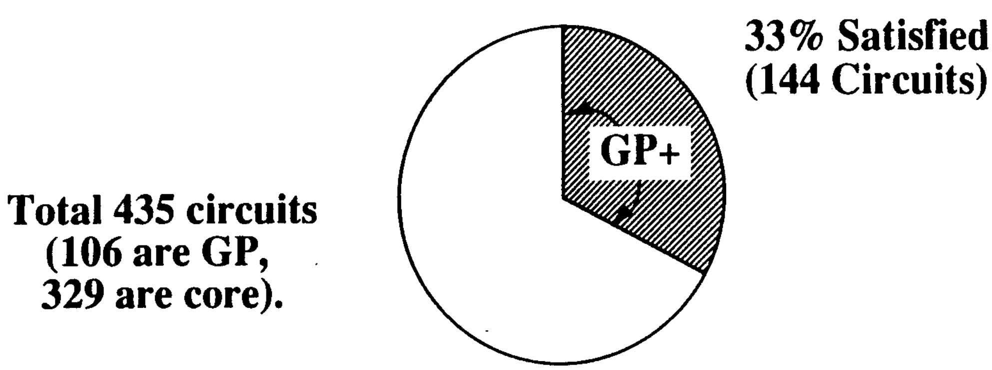
SS/LORAL measured satisfaction of MSS requirements by the number of circuits satisfied, in lieu of percent satisfaction of aggregate throughput. This method provides a performance measure that is transparent to the voice encoding technique used by the different MSS systems. Of the 435 requirements, all 106 GP requirements and 38 core requirements (a total of 33% of the total number of required circuits) can be satisfied by SS/LORAL's architecture. Since core requirements without a specific tactical AJ requirement can be supported in addition to GP traffic, SS/LORAL adopted a category termed GP+. The percentage of GP+ to overall requirements is shown in Figure 4-1.

At the start of the study, SS/Loral was requested to investigate the feasibility of leasing a dedicated MSS channel for DoD use. This approach was perceived as desirable for the DoD because it was believed that costs could be saved over per minute charges. However, SS/Loral concluded that the volume of DoD traffic did not justify a dedicated leased channel.

4.1.1 Space Segment

Comparison of nine candidate commercial MSS systems is shown in Figure 4-2. From the 511 possible combinations of these systems, the MSS architecture recommended by SS/LORAL is an all-bent-pipe system consisting of one Geosynchronous Earth Orbit (GEO) system, one Low Earth Orbit (LEO) system, and one Medium Earth Orbit (MEO) system. Bent pipe systems (e.g., INMARSAT, Globalstar) were chosen in lieu of on-board processing (e.g., Iridium) to permit interoperability among systems. Although bent-pipe systems need regional

• 144 circuits out of a total of 435 circuits in the Brown Book" can be satisfied.



Note: 46% of total circuits can be satisfied if the LPI/LPD requirement is relaxed.

Figure 4-1. Requirements Satisfied

9 candidate commercial MSS systems are grouped in 5 categories:

Category	MSS System
LEO (bent pipe): (Low Earth Orbit)	Aries Ellipso Globalstar
LEO (crosslink):	Iridium
MEO: (Medium Earth Orbit)	Odyssey
GEO: (Geosynchronous Earth Orbit)	AMSC Inmarsat
Little LEO: (below 1 GHz frequency)	Leosat Orbcomm

Figure 4-2. Commercial MSS Systems

gateways and terrestrial backhaul circuits, published service costs estimates for Iridium (the only on-board processing system under consideration) were significantly higher than those of all-bent-pipe systems.

The recommended GEO system is INMARSAT and currently consists of four satellites providing ocean coverage. Terminals operate at L-band frequencies. The next generation INMARSAT satellite will provide five spot beams for concentration of communications in areas of interest and a dedicated L-band package.

The MEO system (Odyssey), being developed by TRW, consists of 12 satellites. This system will utilize L- and S-band frequencies with gateways operating at Ka-band.

The LEO system is Globalstar, which is being developed by LORAL-Qualcomm and will consist of 48 satellites. This system will utilize L- and S-band frequencies with gateways operating at C-band. The satellite antenna design will provide asymmetrical radiation patterns to improve performance. A position location method will provide position accuracy and satellite report structures.

Some of the detailed information about developing LEO systems was not releasable because of proprietary considerations. SS/Loral's approach and methods for evaluating alternative architectures were reviewed by the Government to assure objectivity. SS/Loral developed an open architecture which did not preclude viable future service offerings that could potentially be used by DoD.

4.1.2 Earth Terminal Segment

Three user terminal categories were defined by SS/LORAL depending on the type of platform supporting the terminal. These categories are: shipboard, airborne, and land-based. The number of shipboard terminals is 2,280. As part of the 2,280 terminals, several tri-band terminals for shipboard use were identified for high data rate mobile communications. Tri-band terminals were recommended to ensuring global access via FSS networks and to reduce required shipboard deck space for communications equipment. The number of airborne terminals is 366. The number of vehicle terminals are 570. Thus a total of 3216 MSS terminals will be required to implement this architecture. The total number of terminals for each category is shown in Table 4-1.

Table 4-1. LORAL's Terminal Types for 2006

	MSS
Shipboard	2280
airborne	366
manpack/handheld	570
TOTAL	**3216**

Gateways are used to provide a single hop interface between mobile users and existing terrestrial networks such as the Public Switched Telephone Networks (PSTN) and DISN or to provide an interface between satellite systems of different frequencies. A complete and complicated MSS architecture diagram for the year 2000 is presented in Figure 4-3. A detailed discussion of the architectures features are provided in SS/Loral's final report [Refs. 9 and 10].

4.1.3 Control Segment

LORAL's MSS system control concept is to maximize use of commercial MSS system control networks and integrate this structure with DoD's telecommunication network management structure to provide a "seamless" control network. The MSS will interface to the far-term Government communications system (DISN) on three levels.

The first level of MSS system control will occur at a planned MSS Satellite Control Network (SCN). This facility will be manned by U.S. or allied civilian personnel who will parallel the operations of a DSCS Satellite Control Network for the MSS system. Periodic reports on the MSS system status will be provided to DoD.

A planned MSS Network Control (NC) facility will provide area-wide interfacing between MSS and DISN. The Area Communications and Operations Centers (ACOC) assign user access, access control, call restrictions, call control, and traffic accounting for both DSCS and MSS links. The MSS information is sent to the MSS NC for execution. Thus, DoD retains control of network management, but the MSS NC, which is required to adhere to regulatory and operational constraints of commercial networks, is executor of the MSS system.

A third interface is established via an MSS Terminal Control (TC) on a region-wide basis. DoD will control user assignments of links and equipment based on a hierarchy. The top

level of the hierarchy is accountable for total number of terminals, number of channels, and level of service. User and terminal identification codes will be relayed to DoD NCT to be used in conjunction with call requests for validation and authority to place a call.

The commercial MSS system management functions are defined by International Standards Organization (ISO). This includes: fault detection, configuration control, accounting, performance, and security management. These functions are performed at MSS gateways in addition to translation between signal formats and protocols; thus, the MSS gateway will control call set-up, system performance and monitoring, call disconnect, user billing, and interfacing at baseband level. The DoD NCT will control caller access and management to GEO, MEO, and LEO gateways.

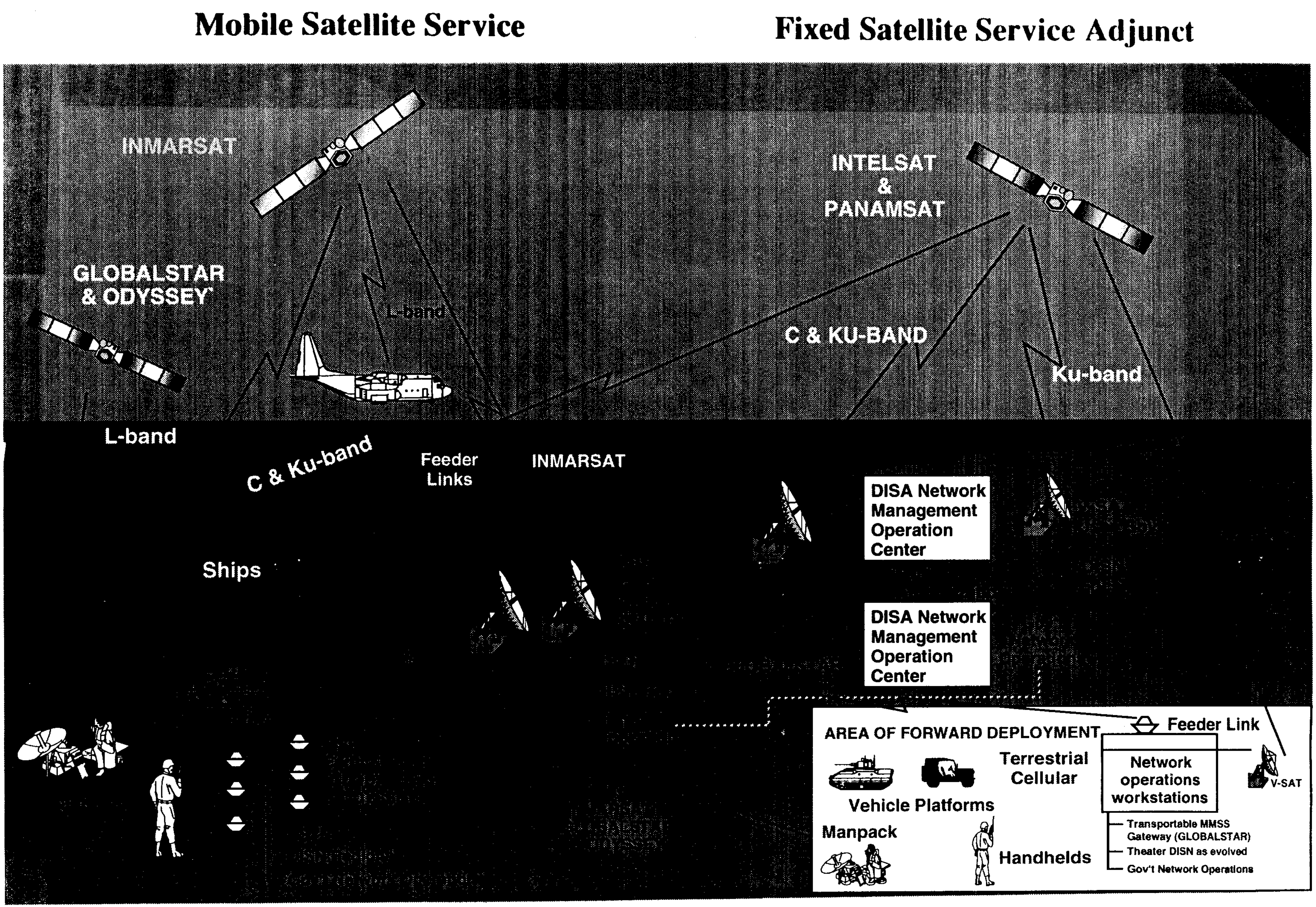


Figure 4-3. MSS Architecture (Year 2000)

4.2 STRATEGIES FOR IMPLEMENTATION OF ARCHITECTURE

LORAL's strategy for implementation of their architecture is driven by the viability of a competitive future MSS market. SS/LORAL forecasts increased competition as new systems begin operation and recommends a flexible approach to exploit commercial MSS systems' evolution in development of a private DoD network. Long term leases of present systems is not recommended. A proposed schedule for implementation is shown in Figure 4-4.

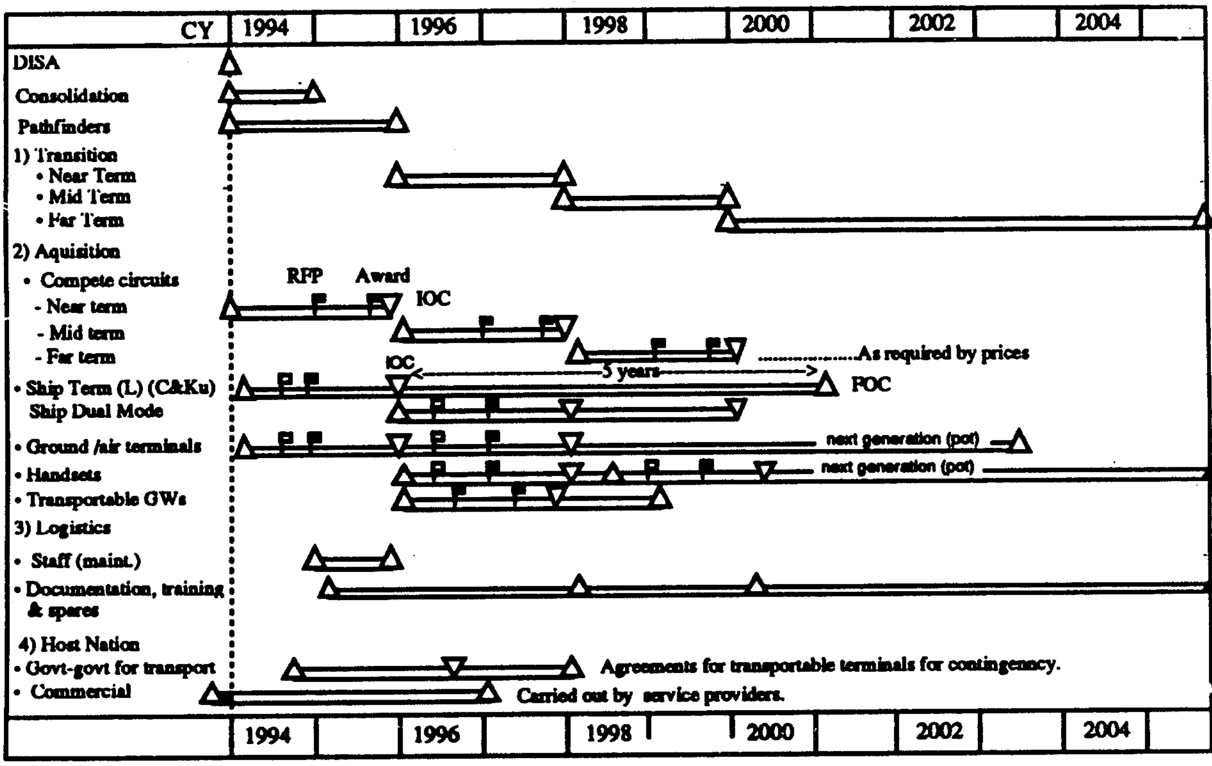


Figure 4-4. Schedule for Implementation Plans

4.2.1 Host Nation Approval

The Host Nation Approval plan, proposed by SS/Loral, is to follow current U.S. Government agreements with foreign governments. In areas lacking MSS service, the U.S. Government will need to negotiate agreements with host nations to deploy and operate a gateway station, or when needed to bypass the local telephone company. In areas where the U.S. can lease services from an established supplier, the system operator obtains the operating license and is responsible for meeting domestic and international regulatory requirements. For the GEO

MSS system (INMARSAT), no additional international agreements are necessary unless 1) access to other land earth stations is desired or 2) a dedicated DoD earth station is needed on non-U.S. territory. For the second case, an agreement would be required from the government of that territory.

For the LEO bent pipe system, the system operator is responsible for negotiating arrangements with designated countries, including gateway charges and traffic handling. Mobile to mobile connections via LEO systems with crosslinks must be obtained through agreements with local country suppliers. Some suppliers will have pre-existing international agreements while other countries may not have agreed to allow crosslink systems to operate from their territory.

4.2.2 Acquisition Plan

The implementation strategy is to acquire resources by an open competition between at least two contractors in each region. Centralized planning, consolidated requirements, and bulk purchases will be used to minimize cost. If offered, short-term leases are preferred to take advantage of possible price wars and other cost-savings brought about by competition. Any innovation in equipment or services will be explored and utilized if it provides added value. The remaining unique government hardware such as enhanced communications security devices must be procured, improved, and developed to attract and retain government users.

4.2.3 Transition Plan

SS/LORAL's transition strategy is to start by managing an initial MSS DoD service with currently operational satellites such as AMSC and INMARSAT. As new satellite systems develop (Globalstar and Odyssey) additional DoD service would transition onto those systems. After 2002, a government private network would be established based on available commercial MSS suppliers. At this point, competition among satellite providers and the possibility of interoperation among systems would determine the private network. However, by 2006 all general purpose traffic including growth in the number of requirements would be supported by commercial satellites.

4.2.4 Logistics Plan

The logistics of SS/LORAL's implementation plan are driven by five factors: documentation, training, staffing, facilities and spares. The documentation provided by equipment vendors will be used to develop a training program for DoD personnel that already have similar skill specialties. These personnel will be assigned to staff existing sites and sites transitioning to commercial systems to operate and maintain equipment and to train additional personnel. Equipment requiring replacement of parts will have spares available at the line replaceable unit level. For more involved repairs, contractor, repair facilities are to be used to save cost.

CHAPTER 5
INTEGRATED COMMERCIAL SATCOM ARCHITECTURE

5.1 BACKGROUND

Assessments of the CSCI study industry teams' recommended FSS and MSS architecture designs together with the results of demonstrations and studies conducted by the study participants have been used by the Government to develop an integrated commercial SATCOM architecture. This architecture supports a combination of fixed and mobile commercial SATCOM services for the Department's users and is based on the findings and recommendations of the CSCI studies. The integrated architecture highlights the desirable features of the contractor developed architectures and will evolve as requirements change.

The purpose of the integrated architecture is to identify cost-effective and viable solutions to peacetime and surge requirements. The integrated architecture thus represents a set of commercial SATCOM capabilities for space, terminal, and control segments that can be used as a whole or in part to meet DoD's present and future needs for general purpose communications services. Figure 5-1 illustrates the integrated architecture concept and the following paragraphs summarize the key features of this architecture.

- The peacetime FSS capabilities are based on a combination of the Hughes and COMSAT recommended architectures. Transponder capacity may be leased from several international (e.g., INTELSAT and PanAmSat) and domestic (e.g., GTE and GE) satellite operators to support mid-latitude (i.e., 70°S to 70°N) coverage on a worldwide basis. A mix of standard commercial off-the-shelf (COTS) terminals operating at C-band and Ku-band support point-to-point, mesh, broadcast, and hub-remote network configurations.

- The peacetime MSS capabilities are based on the designs recommended by COMSAT and LORAL. The INMARSAT satellite constellation would be used to support worldwide, mid-latitude service from shipboard, airborne, and land-based COTS mobile terminals. Higher throughputs from mobile platforms may be achieved using terminals capable of operating at C-band, X-band, and Ku-band. The capabilities of personal communications service (PCS) satellite systems would be used for land-based mobile services as these systems emerge as expected towards the end of the decade.

- Control of commercial SATCOM network operations would be fully integrated with the DISN control concept. A hierarchical management structure having global, area/theater, and regional management centers would accomplish all network monitoring, management, control, and billing functions.

- Capacity to support the surge requirements of a deployed JTF could be available from whole to preemptible portions of leased transponders reserved for this purpose.

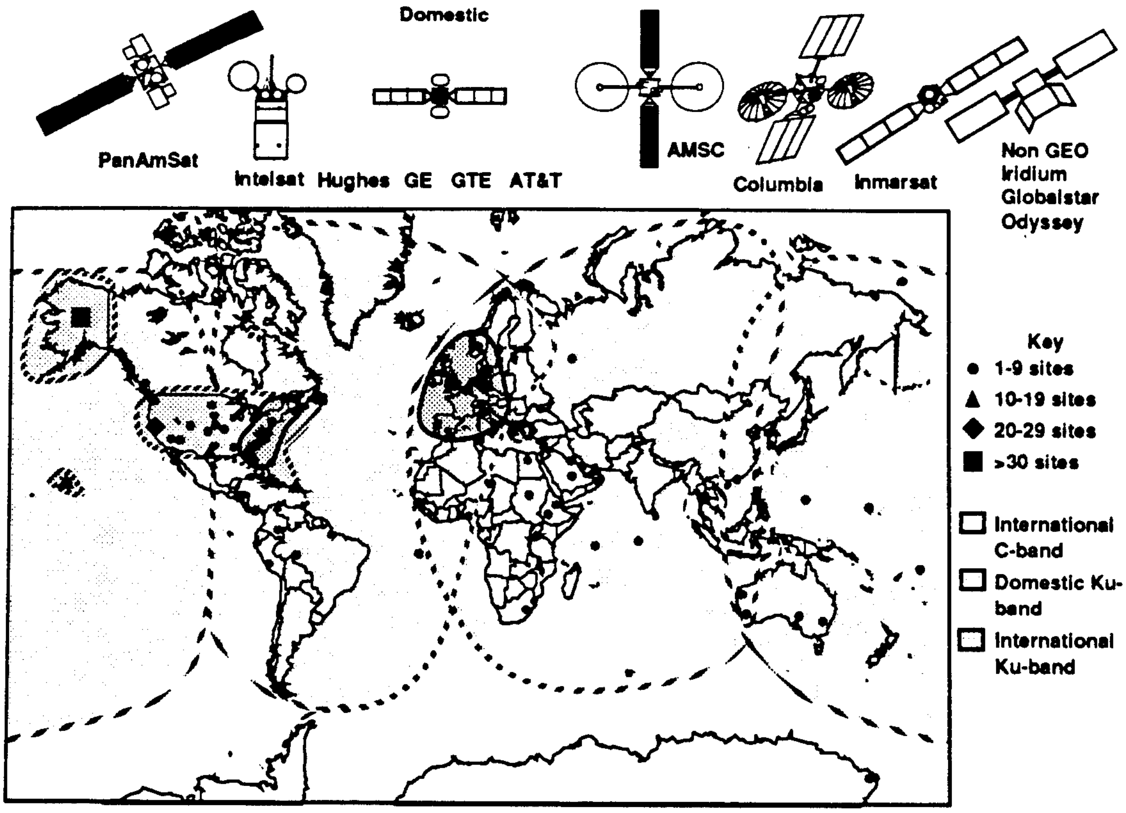


Figure 5-1. Integrated Architecture Concept

The following sections describe the space, terminal, and control segments of the integrated architecture

5.2 SPACE SEGMENT

The integrated architecture will lease a mix of C-band and Ku-band commercial satellite transponder capacity from international and domestic satellite operators. Full coverage of the mid-latitude region between approximately 70°S and 70°N will be acquired to meet the needs of users worldwide. To meet these needs with cost-effective solutions, transponder capacity will be leased from multiple satellite system operators. International operators include: INTELSAT, PanAmSat, and Columbia. It should be noted that INTELSAT is currently the only operator that provides full worldwide, mid-latitude coverage for FSS. PanAmSat will achieve this capability with the completion of their planned satellite constellation in the mid-1990s. To meet projected general purpose peacetime and surge requirements at the end of the decade, the integrated architecture will lease up to approximately 40 C-band and Ku-band transponders. This estimate is based on a design to accommodate all current general purpose DoD requirements; however,

the total is scalable to address growth or a reduction in the requirements allocated to this architecture.

As a general rule, Ku-band capacity will be used in the integrated architecture wherever possible. C-band installations typically require more frequency coordination than Ku-band implementations because C-band is used extensively for terrestrial communications. In addition, the employment of spot beams and thus the high downlink EIRP available at this Ku-band permits the use of small, low cost terminals for many applications. Ku-band spot-beam coverage, however, is typically limited to regions having a high population density, whereas C-band coverage is available worldwide through broader coverage hemispherical and global beams. Thus, substantial use of C-band capacity is required in the integrated architecture to ensure worldwide mid-latitude coverage.

Acquisition of fixed commercial SATCOM capabilities in the integrated architecture will be accomplished by a centralized top down approach using a consolidated set of requirements. The proposed FSS space segment acquisition strategy is depicted in Figure 5-2.

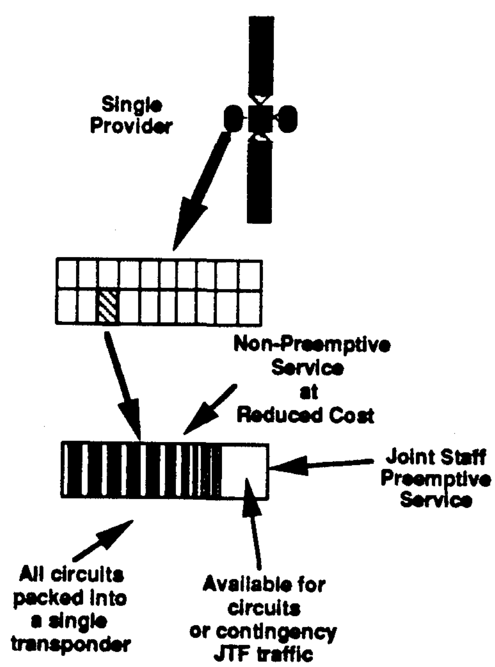


Figure 5-2. FSS Space Segment Acquisition Strategy

Leases for individual commercial SATCOM circuits were awarded on the basis of competitive bids. While the competition to provide services ensures some degree of cost

savings, additional savings may be accomplished through quantity discounts available by leasing full or partial transponders on a long term basis and "bundling" present circuits and trunks onto these transponders. Savings are realized since the cost of leasing a whole transponder is significantly less than the total cost of the individual circuits. Transponder power and bandwidth beyond that needed for non-preemptible service is reserved for preemptible service and controlled by the Joint Staff. This strategy enables DoD to manage the use of the leased resources in an efficient manner while ensuring sufficient capacity is available on a preemptible basis to support the needs of a deployed JTF.

The majority of near-term needs for MSS capabilities are to be satisfied at L-band by the INMARSAT system. INMARSAT is currently the sole vendor providing worldwide, mid-latitude coverage for mobile voice, low rate data (i.e., $\leq$ 64 kbps), and facsimile services. In the integrated architecture, these services will be acquired on a dial-up pay-per-minute basis. As PCS systems become operational towards the end of the decade, DoD will use their services primarily for land-mobile users. To meet peacetime and surge requirements for mobile communications service by the end of the decade, it is estimated that DoD will use up to 5 million minutes per year of MSS system calls. However, INMARSAT does not plan to offer leases of a dedicated DoD channel or portion of a transponder.

The integrated architecture will use FSS transponders as an option to address mobile user (i.e., Navy) needs for moderate to high data throughput (i.e., > 64 kbps) that cannot be accommodated on the INMARSAT system. Leased transponders to support this capability will be either C-band through a global beam or Ku-band through steerable spot beams, if available. The architecture mix of C-band and Ku-band transponders for this service will depend on the availability of the desired transponder and antenna combination, the requirements of the network, and other operational considerations including:

- Frequency coordination – Ku-band operations have less potential than C-band for interference with terrestrial communications and hence entail fewer frequency coordination and host nation approval (HNA) issues (e.g., for operations in coastal waters).

- Throughput – For a given terminal size, Ku-band steerable spot beams will generally support higher throughputs than C-band global beams.

- Operational security – Use of the steerable spot beams by a Navy task force requires coordination with the satellite operator to maintain coverage. For certain operations disclosure of force position would be a violation of operational security, thus necessitating the use of C-band global beams.

5.3 TERMINAL SEGMENT

This section describes the capabilities of the terminal segment of the integrated architecture that will support the full range of general purpose requirements of DoD users. While this segment will consist of a mix of terminals that operate at L-, C-, and Ku-band, it must be noted that in some cases, FSS systems (i.e., those operating at C-,and Ku-band) are used to satisfy the needs of mobile users, and MSS systems (i.e., those operating at L-band) are recommended for use by a small group of fixed users. These applications may result from the unique nature of the requirement and the desire to minimize cost and operational impacts.

For all transportable and fixed applications, the integrated architecture uses three categories of terminals based on antenna size and supportable throughput: VSAT - 2.4m (Ku-band) and 3.8m (C-band); Trunk - 6.1m; Hub - 11m. As indicated, the VSAT category uses two sizes of antennas depending on the frequency band of operation. The larger 3.8m VSAT aperture is needed at C-band to support throughputs comparable to those of the Ku-band 2.4m terminal. The size differential between the C-band and Ku-band apertures is necessitated by the differences in space segment capabilities as described in the previous section. The VSAT category may support user throughputs in the range 75 bps to 1544 kbps; trunk terminals support throughputs in the range of 1544 kbps to 8.0 Mbps; hub terminals would be used in applications that require throughputs in excess of 8.0 Mbps.

For all mobile applications, the integrated architecture uses categories of terminals based upon the users platform: aeronautical, maritime, or land-based. Aeronautical terminals operate at L-band using a 0.85 m phased array antenna that can support up to 9.6 kbps. New specially developed aeronautical terminals operating at C-band and supporting 3088 kbps from aircraft are anticipated in 1998. Maritime terminals currently operate at L-band using a 1 m antenna and support data rates up to 64 kbps. New maritime terminals are being developed that will operate at C- and Ku-band using a 1.8 m antenna and will support data rates up to 1544 kbps. These terminals are expected to be widely available off the shelf by 1996. Land-based mobile terminals (e.g., suitcase, briefcase) currently support 64 kbps at L-band using a 0.5 m antenna. New handheld terminals accessing PCS systems will become readily available towards the end of the decade. As these systems become operational, land-based mobile requirements should be competed between several PCS competitors (in addition to INMARSAT) to ensure low cost pay-per-minute services.

Modifications to L-band maritime terminals and a land-based earth station will provide multipoint to multipoint push-to-talk conference capabilities. This modification will loopback the land earth station and equip maritime terminals with push-to-talk handsets. The loopback is required since INMARSAT is not designed for direct communications between users. This conference network requires encrypted voice possibly provided by VINSON and SUNBURST encryption methods since STU-III does not support multipoint requirements. A second terminal modification will allow point-to-multipoint and multipoint-to-point data exchanges to control an Information Exchange System (IXS). This modification will integrate L-band equipment with existing IXS baseband processors. This modification will require development and determination of an appropriate encryption system.

Tri-band shipboard terminals are included in the integrated architecture to ensure access to either C-, X-, or Ku-band services from these platforms while minimizing shipboard antenna space. These terminals can use current technology supplemented by an antenna modification to develop a tri-band capability.

Key features of the terminal segment design that enable the architecture to be cost-effective and responsive to user needs include:

- Use of customer-premise equipment (CPE). The design approach minimizes the costs associated with terrestrial tail leases.
- Extensive use of COTS equipment. The majority of terminals used in the architecture is standard commercial off-the-shelf equipment. The widespread use of non-development item (NDI) systems minimizes costs and ensures availability from a number of different manufacturers.
- Use of standard terminal categories. The architecture uses a standard set of fixed and transportable terminals based on terminal size These terminals are chosen to support the full range of user requirements and to reduce the variety of equipment fielded, thus minimizing training and logistics support time and costs.
- Use of tri-band terminals. The architecture fully supports the use of terminals capable of operating at C-, Ku-, and X-band on platforms (e.g., ships) having constraints on space available for antenna placement.

5.4 CONTROL SEGMENT

The control segment of the integrated architecture is fully integrated with DISN control concepts. A three level hierarchical management structure similar to the DSCS management structure will be used. The global (Level 1) management center will be the primary interface

between commercial providers of leased satellite transponders and DoD. The area/theater (Level 2) management center will be responsible for network operations on transponders, user billing including payment for foreign half circuits, and record keeping. Regional (Level 3) centers will oversee DoD services using commercial public MSS gateways.

Global network management will be performed at a primary facility located in CONUS. This facilities responsibilities are monitoring area management facilities to provide backup assistance to failed area facilities, analyzing network operations trends, directing activation of operational transponders, and coordinating inter-area transactions such as planning contingency operations.

Area management will be performed in a particular theater of operation. Area management controls the system elements and network transport layer entities such as switches, DISN MSS gateways, and router. Additionally, the area management monitors and controls sub-networks that cross regional boundaries.

Actual network management and control is accomplished at the Regional and Base level. Regional management efficiently interconnects military installations, tactical command posts, and other facilities within a geographical region. These management centers also provide consolidated access to non-DISN resources, optimize use of network resources, and control day-to-day operations. For FSS networks, regional management performs resources allocation, space and terminal configuration, network performance, fault monitoring, accounting and billing, and security management. For MSS networks actual management is performed by the commercial MSS Network Control Center (NCC).

Base management has control over all earth station network elements in its service region. This facility communicates with each site by orderwire via satellite and with a regional and area management facility to provide redundant monitoring and control. Two databases, one each for fixed and mobile sub-networks, are maintained that monitor all terminal operations within that service region. These databases monitor physical and operational configurations of each terminal and performance status of all circuits and RF carriers. An associated expert system reports and resolves problems, tracks processes, and provides automated diagnostics. This control concept is shown in Figure 5-3.

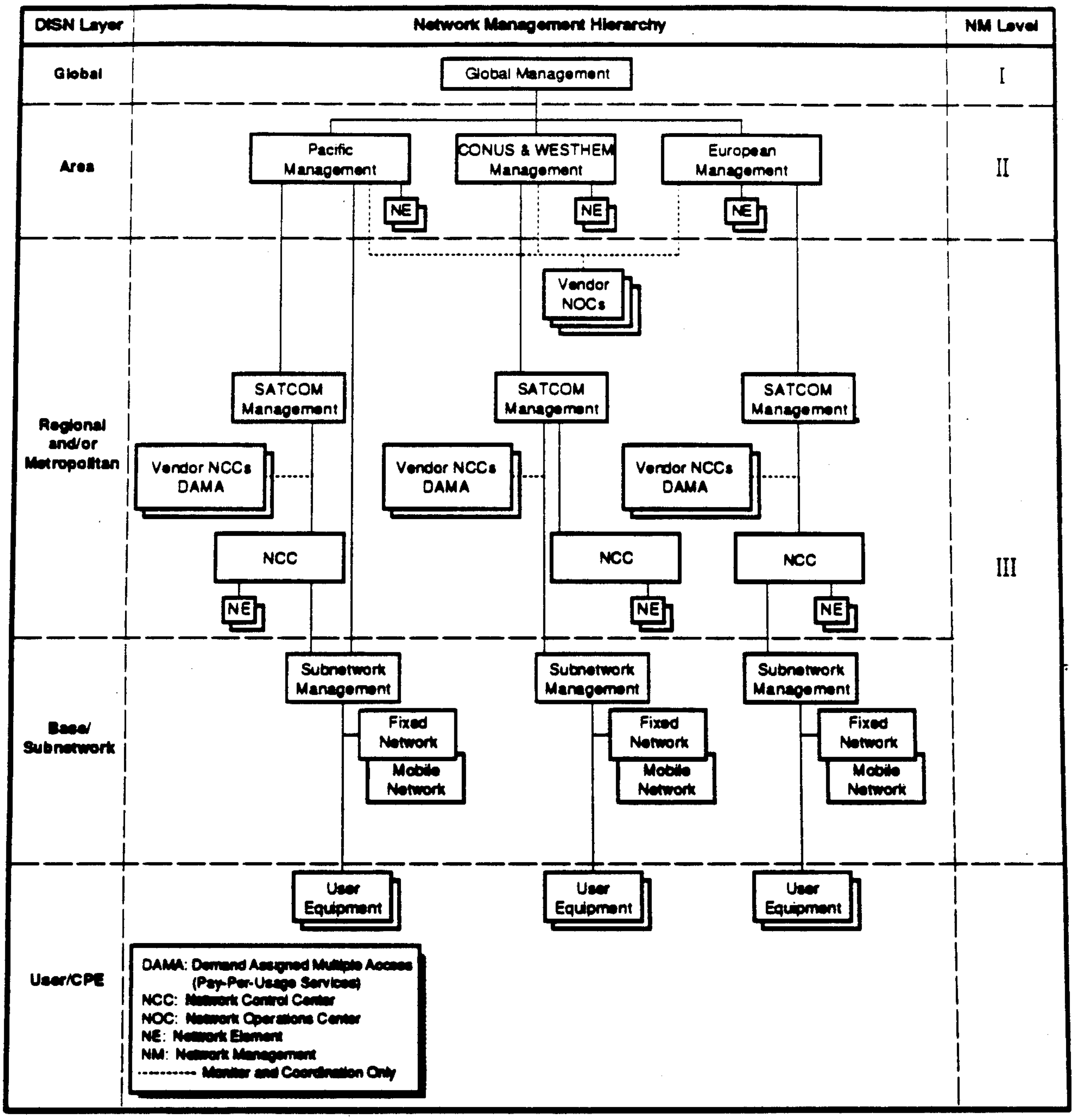


Figure 5-3. Integrated Architecture Control Hierarchy

The centralization of information is achieved through use of a distributed client/server architecture. Government Network Management Profile (GNMP) standards will be followed by implementing Government Open Systems Interconnection Profile (GOSIP) management capabilities.

Key features of the integrated control segment are:

- An earth station monitor and control system will manage all customer premise equipment from a single PC platform.
- Cost will be minimized through reduced staffing requirements and use of COTS equipment and software.
- Management will be more responsive to bandwidth on demand, on-call needs and emergency needs through centralized information centers.
- DoD control will be maintained by placing management and control terminals on military installations.

CHAPTER 6
VULNERABILITY OF COMMERCIAL SATELLITE SYSTEM

An independent internal Government study was conducted to determine the vulnerability of commercial satellite systems. Protection requirements for the CSCI architecture vulnerability and system susceptibility were derived from the user requirements in the ISDB. Detailed results are classified and are not releasable to non-government organizations but an unclassified summary of the recommendations are presented in this section.

There are four categories of threats by potential adversaries: exploitation, interception, user geolocation, jamming and deception. Circuits are exploited by monitoring traffic and using signal analysis and pattern usage to deduce the user and mission. Circuits can also be intercepted using various methods anywhere along the communication link. Earth terminals are geolocated by applying direction finding techniques to available signals. Satellites are degraded by unintentional or purposeful signal interference, commonly referred to as jamming. The entire network or a portion of the network can be deceived by introducing false operational, signaling, or coordination information.

Since these potential vulnerabilities are associated with the use of any commercial satellite, mission planners need to be aware of these risks. A balance between the acceptability of the risk and the degree of an adversaries technical sophistication needs to be determined for each mission.

Several recommendations for reducing vulnerability and mitigating susceptibility of commercial satellite systems are as follows:

1. Use whole transponders and manage transponders under DoD network control.
2. Distribute traffic over multiple satellites.
3. Attempt to ensure compatibility between commercial terminals and DoD AJ modems for missions that require protection.
4. Attempt to ensure that private terminals which recognize encrypted DoD protocols are independent of commercial signaling practices.
5. Attempt to maintain TT&C operational integrity through sustained use of encrypted or authenticated satellite command uplinks. This would be to ensure that selected satellite contractors implement routine procedures to maintain command protection.

6. Closely examine selected satellite systems to ensure that military operations are not compromised by satellite owner, coordination circuits, or consortium administrative and billing practices.

7. Carefully select satellite systems for transportable and mobile terminals since these terminals can have a high potential for geolocation depending on the satellite.

8. Attempt to eliminate automatic responses to radio inquiry and automatic responses of terminal identification or location as with the INMARSAT system. This requires modification of terminals to support EMCON conditions.

9. Continue to consider crosslinked LEO systems such as Iridium since this system could be less susceptible to adversary actions (exploitation, geolocation, jamming, and deception).

CHAPTER 7
NEW TECHNOLOGIES AND INNOVATIVE CONFIGURATIONS

7.1 ASYNCHRONOUS TRANSFER MODE (ATM)

The ATM concept was demonstrated to show the viability of extending global grid or DISN capabilities into a tactical theater via satellite at 45 Mbps. Since satellites are the primary communication medium to joint tactical forces (JTF), the operational benefit of ATM is to extend switched traffic into a theater where there may not be a fiber ATM infrastructure. This new means of telecommunication provides multimedia (voice, data, and video) traffic at variable bandwidths, real-time network reconfiguration capabilities, and access to all types of information within the JTF communications infrastructure. This demonstration was the first to establish ATM over a satellite link.

A scenario of two interactive video teleconferences, one for mission planning (using a shared whiteboard of map imagery) and one for telemedicine (using a shared whiteboard of radiology images) demonstrated the multimedia and access to information concepts. Variable bandwidths were demonstrated by operating one teleconference at 24 frames per second and the other at 30 frames per second. The configuration of using commercial-off-the-shelf (COTS) equipment and interfacing fiber optics with the satellite demonstrated that the ATM network can operate transparently. An example of the demonstration configuration is shown in Figure 7-1.

The demonstrations were successful over the course of 2 weeks due to skilled engineers and technicians maintaining the system. Satellite burst errors, switch drop-outs, operational mis-communication, and experimental application software created occasional problems but were generally transparent to the attendees. However, for sustained tactical operations, this system needs more robustness and established operating procedures.

The type of protocol used (TCP/IP, X-TCP/IP, SSCOP) was an issue with this system. Standard TCP/IP has a small packet size (48 cells). TCP/IP requires an acknowledgment of one packet receipt before the next packet is sent. This reduces link performance by satellite communications since a two-way time delay for packet receipt and acknowledgment amounts to 1/2 sec. X-TCP/IP extends the packet size of TCP/IP which reduces, but does not eliminate, the wait delay between packets. Both these protocols are universally used standards, but do not deal with time delays on the order of magnitude of satellite communications. SSCOP, as implemented by COMSAT, was designed to increase the packet size and eliminate

acknowledgment delays by requesting only cell loss retransmission not entire packets. The suitability of SSCOP for satellite operation was favorably demonstrated by in-lab and over the satellite tests and is presented in the ATM technical report [Ref. 1].

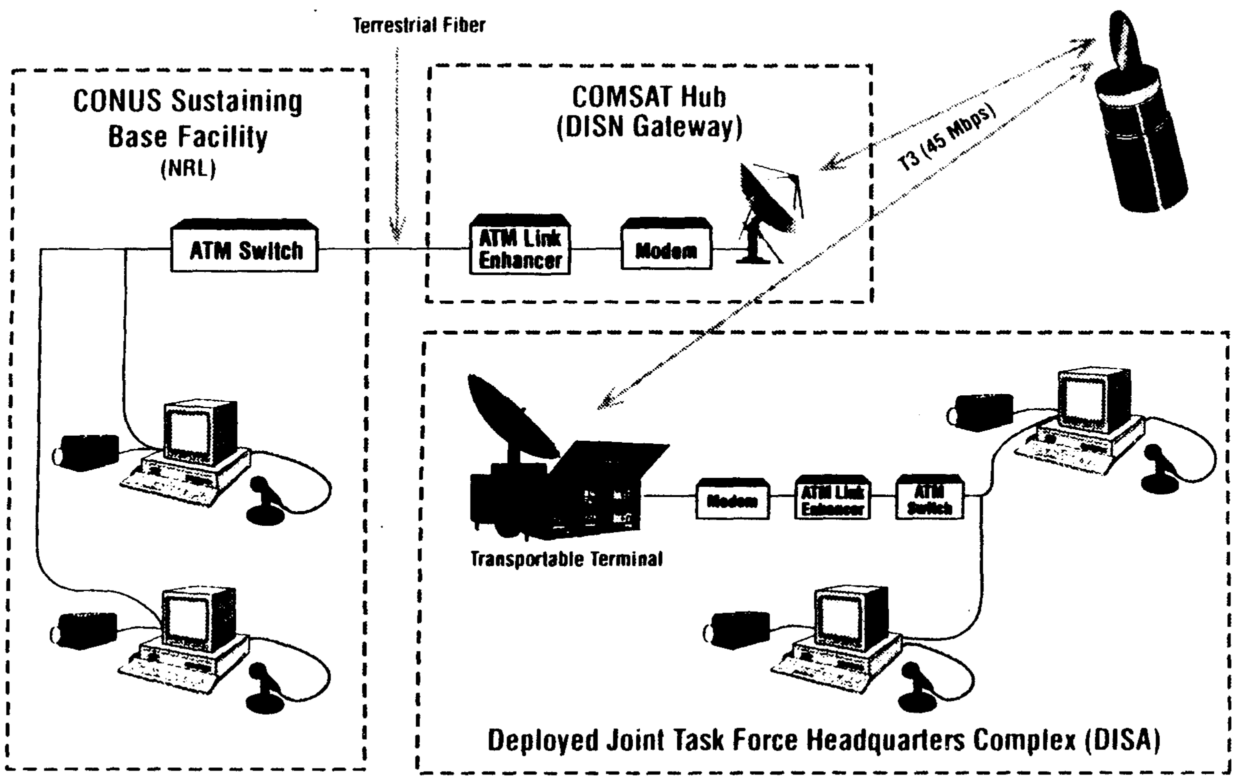


Figure 7-1. ATM Demonstration Hardware

7.2 COMPACT USER PULLED INTELLIGENCE DISSEMINATION (CUPID)

The CUPID concept was demonstrated to show the feasibility of disseminating high speed imagery and command data from a hub site (7.6-meter antenna) to a small tactical site (1-meter antenna) and of transmitting low speed imagery requests and gun camera video data from a small tactical site to a hub site. The high speed imagery link operated at 2 Mbps providing an image of 1024 x 1024 with 8 bits per pixel. An image disseminated on this high speed link was received within 30 seconds. The low speed link operated at 128 kbps TDMA providing the tactical user a 9.6-kbps burst. A gun camera video sent to the hub on this link took 4.5 minutes. An example of the demonstration configuration is shown in Figure 7-2. The equipment that made this new configuration possible was a high speed modem developed for Hughes and proprietary software (RapidView) to establish a Client/Server architecture on a UNIX system. The benefit of this new configuration using COTS equipment is an improvement in tactical communications using available satellite transponders and earth terminals.

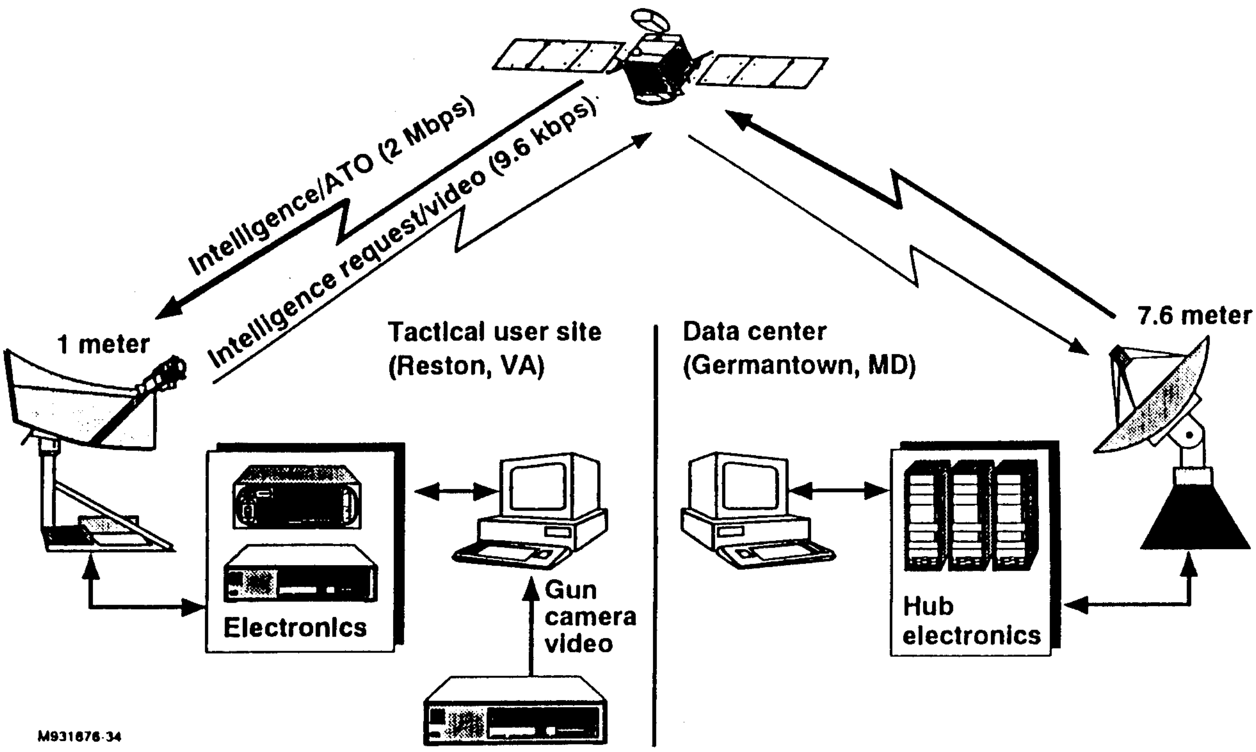


Figure 7-2. CUPID Demonstration Architecture

The speed of receiving an image at a tactical site was impressive. The slight time delay in transmitting an image to the hub over a low speed link was acceptable, although a capability to demand more bandwidth (increasing from 9.6 to 128 kbps) when sending images to the hub would be possible with some additional equipment modifications.

7.3 MULTI-BAND ANTENNAS

The purpose of this study was to investigate the feasibility of modifying existing military earth terminals (representing heavy, medium, and light terminals) so they can provide tri-band operations (C, X, and Ku-band). The two methods, examined in detail, of modifying the antenna system were to 1) install additional C and Ku feeds on opposite sides of the existing X-band feed and retain the existing fixed subreflector or 2) install all feeds equally off-axis in a circular configuration and use a rotating subreflector to ensure that one antenna feed is on-axis.

The first method decreases maximum antenna gain and perturbs antenna patterns by being slightly off-axis. The decreases in performance varies quantitatively with the main reflectors size and shape. Thus, this option is technically suitable for standard Cassegrain antenna systems that are symmetrically shaped but not suitable with dual shaped reflector systems.

The second method also has degraded performance in terms of small (< 0.2 dB) gain losses, which are acceptable for both antenna systems. However, this method is more mechanically complicated since the subreflector must rotate.

The result is that tri-band operation is feasible. However, the operational concept in using tri-band military terminals, needs more development. Questions remain about which frequency should be used since only one frequency band can be used at any given time. The benefit of this tri-band antenna is the flexibility to use various commercial satellites at either C- or Ku-band or military satellites at X-band.

7.4 PERSONAL COMMUNICATIONS SATELLITES (PCS) AND HANDHELD TERMINALS

The goal of personal communication satellites is to allow worldwide connectivity using handheld terminals. This goal arose from the widespread use of terrestrial cellular radios, which led to the widespread use of small handheld terminals. The satellite community has also proposed the use of similar handheld terminals, expecting that their use will be widespread. The user will benefit from a low cost, personal communication satellite system with small, handheld terminals that will work almost anywhere in the world. COMSAT is investigating the market demand and the cost of development of such a system. However, uncertainty exists about which low earth orbit (LEO) system will emerge and what the final cost will be for this system. Only INMARSAT-P has announced that the PCS used by these terminals will be either a standard geosynchronous orbit or a medium earth orbit.

With new MSS services, commercial handheld terminals will become available in the late nineties. The INTELSAT Standard M terminal is a precursor to these handheld terminals. Studies on bandwidth limited efficient modulation, quality voice processing algorithms at lower and lower rates, and better signaling techniques will assist in development of handheld satellite earth terminals. Research is ongoing to determine if in the far-term dual use (both terrestrial and satellite) commercial terminals will be feasible and cost-effective.

7.5 DEMAND ASSIGNED MULTIPLE ACCESS (DAMA)

Demand assigned multiple access (DAMA) has been employed recently in the commercial VSAT marketplace to optimize the use of space segment and to support a set of users with non continuous or dial-up communications requirements. Using DAMA, the

commercial satellite network operator need only purchase sufficient satellite bandwidth and power to support a subset of the total potential communications circuits rather than the entire set of requirements since not all communications circuits must be satisfied simultaneously. The parameter which must be traded against the cost of space segment is the wait that a user must endure until a circuit becomes available. This waiting time is dependent on the connection statistics of the user community (probability of blockage) and the number of circuits that the space segment is capable of supporting. Modern commercial VSAT DAMA networks allow for the network operator to adjust the circuit waiting time by either purchasing more or less space segment. This feature allows the network operator to always keep the network optimized for user needs as well as minimum cost.

For DAMA to be successfully employed in military communications networks, users must be identified who can operate with dial-up services rather than continuous services and priority schemes must be employed. While dial-up services are not normally observed in today's military satellite communications networks, the use of this type of service offers cost savings over continuous links with call waiting times under control of the network operator. Dial-up services in mesh VSAT DAMA networks also offer the user the ability to participate in a thin route telephone network with all the features and services found in terrestrial telephone networks. Thus, modern commercial DAMA VSAT technology can provide more communications services to the military while offering the ability to manage space segment costs.

7.6 EMBEDDED ENCRYPTION

Currently, encryption devices for mobile satellite terminals are STU-IIIs. When new small mobile satellite terminals are developed, they will be approximately the same size as a STU-III. Thus encryption needs to be embedded within these small mobile satellite terminals. Research has shown that it is feasible to develop and implement embedded digital encryption systems. This technology will lead to secure handheld satellite terminals to support the new Personal Communications Satellites.

7.7 NETWORK INTEROPERABILITY AND TRANSPORTABLE GATEWAYS

The concept of network interoperability is to colocate large commercial terminals with certain large military terminals to share common multiplexers and baseband equipment in support of traffic on both systems. In the near term, the multiplexing equipment is expected to be capable of remote configuration. In the far term, the multiplexer equipment might be replaced

by ATM switches for cost-effectiveness and for bandwidth on demand. Control of both systems (commercial and military) will be incorporated for simplicity and to reduce cost.

The concept of transportable gateways in support of MSS was demonstrated by LORAL in three stages. The first stage used a CDMA vehicular mobile phone to connect to the public switched telephone network (PSTN) through emulation of a Globalstar satellite (LEO) and gateway. The Globalstar emulation was necessary since this satellite system is not in existence. The second stage connected a VSAT to the emulated Globalstar gateway. The VSAT transmitted to a Hughes Galaxy-IV satellite (GEO) and was received by a second VSAT, which now became the connection into the PSTN. The third stage simulated interoperability between MSS assets by extending the PSTN to an INMARSAT earth terminal. That terminal transmitted over an INMARSAT satellite to an INMARSAT-A terminal.

Voice quality of the demonstration was excellent throughout the stages. A time delay, during the last stage of the demo, using two GEO satellites was noticeable. However, if the multi-hopping system was over several LEO satellites (which is the actual intended use of transportable gateways rather than the simulation), the time delay would not have been noticeable.

7.8 EXPLOITATION OF DIRECT BROADCAST SERVICES (DBS)

DBS is scheduled for commercial operation in 1994 to transmit a high data rate (150 channels of video) to highly transportable, small terminals (approximately 1 foot antennas) using Ku-band. The new technology developed to enable this system's operation is the high gain downlink antenna, high power downlink transmission, and the digital video compression. As a result, the receive terminals can be very inexpensive and compact.

This new technology could apply to DoD as a means for high data rate, one-way transmission to small, highly transportable terminals for missions such as intelligence dissemination. Military applications of Direct Broadcast Services include broadcast of weather, training, entertainment, intelligence, maps, and archive information to deployed users equipped with very small, inexpensive receiving equipment.

7.9 ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)

The ACTS satellite will demonstrate many new capabilities such as operations at Ka-band (20/30 GHz), very narrow spot beams with high radiated power, high gain antennas allowing high data rates into very small VSAT-size terminals, broadband digital communications into smaller portable terminals, and adaptive on-board communications processing. It operates at data transmission rates that extend over the full range used by the worldwide telecommunications industry, including terrestrial fiber. Thus, it can extend the new U.S. national Gigabit per second data highway into areas of the U.S. that cannot economically be reached by terrestrial fiber.

ACTS opens up a new band of frequencies at 20 and 30 GHz that significantly expand the radio frequency spectrum and, hence, data capacity available to satellite systems in general.

High power spot beams, hopping over regions, concentrate the satellite's energy only on the stations for which a message is intended. This avoids waste of the precious space segment power resource and makes possible delivery of messages to very small earth terminals. In addition, a steerable spot beam provides communications to mobile terminals on land, air, and sea vehicles. This new spot beam provides transportable and mobile access and LPI/LPD advantages for certain supported core circuits.

High gain antennas that vary the antenna pattern on demand accommodate changes in the geographical distribution of the traffic demand. An onboard microwave switch matrix (MSM) interconnects any three of the high gain beams for very wideband operation -- 900 MHz bandwidth. This makes it possible to support the same high transmission rates used by terrestrial fiber optic links.

ACTS uses a new adaptive onboard signal regeneration process to harness this new frequency band for commercial application. This further enhances the capability to operate with small earth terminals. Transmission errors are corrected onboard and also at the earth station receivers to yield very low error rates. Adaptive application of error correction and signal redundancy combats the loss of performance during heavy rain.

Wideband transmission up to 25 Mbps between VSAT terminals and up to 25 Mbps to aircraft using small phased array Ka-band antennas will be possible with ACTS. This is a precursor to evolving broadband digital ISDN (ATM) transmission up to OC 12 rates.

Traffic channels are assigned on demand from a pool of channels. They are made available when a user requests a channel and are returned to the pool for use by others when a call is completed. This greatly increases the efficiency of utilization of the previous space segment resource.

Two families of earth terminals have been or are being developed for performing demonstrations. One family comprises T1 VSATs that can support communications to rates of 1.544 Mbit/s between the VSAT terminals. Twenty of these terminals have been purchased by various private and government entities and are available for demonstrating ACTS' unique communications capabilities by experimenters. A second family comprises slightly larger transportable high bit rate earth terminals. These are now being readied and will be available by the third quarter of 1994 for performing demonstrations at transmission rates up to OC 12 (620 Mbit/s). Thus, in the next 2 years, ACTS will provide an opportunity to test many new satellite communications roles important to government uses.

7.10 DIVERSITY

Investigation into the approaches to mitigate against certain levels of jamming threats has lead Hughes to select a diversity approach for communications links carrying DoD traffic. The diversity approach capitalizes on the inherent low cost of commercial space segment and terminals by adding a second terminal at each site having stressed traffic requirements. The second terminal would access a different commercial satellite than that carrying the unstressed commercial traffic. Destination terminals would have to be equipped to support stressed traffic over the diversity satellite. Since most sites having stressed traffic requirements of less than 1.544 Mbps (even though the unstressed data rate may exceed 1.544 Mbps), almost all diversity terminals can be implemented as VSATs. Thus, it can be added to sites without interrupting existing communications traffic.

While diversity offers an inexpensive method to mitigate against a nuisance jamming attack on the DoD commercial transponder carrying unstressed traffic, it is not the answer to all jamming attacks. In fact, diversity transmission should only be fully effective against nuisance jamming threats (unintentionally caused interference).

7.11 INMARSAT PUSH-TO-TALK CONFERENCING

This task is examining use of one INMARSAT channel for a conference by modifying INMARSAT M mobile terminals and a hub land earth station. This innovative configuration will eliminate the need for several point-to-point circuits to establish a pseudo-conference network. The motivation for this study is to determine whether the terminal modifications are more cost effective than leasing several INMARSAT channels. This concept will be demonstrated in March 1994.

CHAPTER 8
GOVERNMENT EVALUATION OF CONTRACTORS ARCHITECTURES

8.1 EVALUATION OF CONTRACTORS ARCHITECTURE

In general, the contractors' final commercial SATCOM architecture and operations concept reports addressed all requirements of the statement of work and followed Government guidance and comment. However, the following topics need some qualifications and include: systems, satellite payload, Host Nation Approval, requirements, and encryption.

8.1.1 Systems

Since it is unclear which mobile satellite systems will emerge in the future, all potential mobile service providers were initially studied by SS/LORAL. In narrowing all the possibilities, Odyssey and Globalstar were chosen to be components of the SS/LORAL MSS architecture. The use of other potential service providers such as Iridium is not precluded in the design but was not developed in more detail. In fact, the satellite crosslink capability of Iridium would enhance and simplify SS/LORAL's MSS design since regional in-theater deployed and shipboard gateways would be unnecessary. However, SS/LORAL predicts that Iridium's crosslink technology will significantly increase its service costs in comparison to other system's concepts.

Details about emerging INMARSAT services such as INMARSAT P, expected to be available in the near term, were not given by any contractor team to the Government. This omission was attributed to proprietary issues. More information about this system's capability would have been useful in developing near-term architecture opportunities.

8.1.2 Satellite Payload

The use of Ku-band steerable spot beams has been too simplistically presented by the contractors. Although use of a steerable Ku-band spot beam would increase the data rates achievable to small tactical terminals such as those used by the Navy, as many as seven transponders would have to be leased to secure uncontested control of the spot beam steering. The Government may not have sufficient requirements within one spot beam to justify leasing more than one transponder. High demand for Ku-band spot beams requires an early commitment or reservation to obtain these resources for use in the future. Any commitment at this time to resources for future use is premature. Thus, the utility of leasing Ku-band steerable spot beams

needs to be revisited in the future. In addition, the use of the steerable spot beams to cover deployed units (such as a Navy battle group) requires the release of force positional data to the satellite operator TT&C facility, which may compromise operational security.

The difference in the number of proposed transponders for FSS between COMSAT (41) and Hughes (22) is due to differences in analysis methods and to the number of different satellite operators used in each architecture. COMSATs architecture used eight different satellite operators, which required 39 transponders, while Hughes architecture used three different satellite operators requiring 22 transponders. COMSAT has distributed the requirements among more satellites thus lightly loading several transponders. Hughes was able to concentrate the requirements into fewer transponders. This difference shows the range of transponders potentially needed to support all general purpose requirements. Actual satellites to be used and specific transponders required will be determined by detailed transponder loading analysis prior to implementation.

8.1.3 Host Nation Approval

Obtaining Host Nation Approval remains an issue because the CSCI contractors were prohibited from contacting foreign government representatives for information pertaining to hypothetical deployment and implementation plans. Although a time frame was estimated by Hughes for negotiations with foreign countries, specific details about the process and cost charges remain unclear. For example, if a network using TDMA supports communications links to several countries, the billing process and obtaining landing and operating rights for varying amounts of traffic to and from each country remain issue that can only be resolved by negotiating with the countries.

8.1.4 Requirements

The requirements for FSS and MSS were studied carefully by all contractors but were interpreted differently due to different technical assumptions. MSS networks, being served by MILSATCOM UHF, do not have all traffic statistics such as duty cycle needed for commercial MSS solutions. COMSAT and SS/LORAL developed their own traffic models used in determining the number of call minutes needed for a given network. The variability in the models is also reflected in the cost analysis.

It was noted by COMSAT and Hughes that the requirements lacked any transaction oriented requirements (such as a credit card verification schemes useful for finance and logistics operations) that would justify hub to VSAT spoke operations. These requirements are not easily identified because military users are not familiar with this technology and this service is not currently available on military satellites. Since these requirements are still in a more qualitative form they need to be studied at a higher level. This work remains to be done through CSCI's Follow-On pilot program for a VSAT network.

8.1.5 Encryption

For FSS, remotely controlled unmanned terminals were proposed by Hughes. Link encryption of control information would be used to mitigate the potential vulnerability of these terminals to exploitation. Network encryption devices are commercially available, however, some assessment of their performance and determination of cost needs to be completed.

In addition, for MSS, the use of encryption devices for multicast operation needs to be examined further since STU-III link encryption devices are designed for point-to-point operation only. The requirements exist for this type of encryption; however, commercially available off-the-shelf technologies to implement this capability have not been fully developed. Additionally, non-developmental items (NDI) encryption devices have not been introduced by the military for use. This device needs to be low cost and provide secure mobile voice communications in a multicast mode of operation.

8.2 ASSESSMENT OF CSCI GOALS

The CSCI program was funded to determine specific, implementable solutions for using commercial satellite capabilities to satisfy DoD communications requirements. The program was conducted under the following guidelines:

- Develop innovative commercial system architectures.
- Objectively and thoroughly size the capabilities of commercial FSS and mobile satellite systems.
- Assess the commercial systems capability to support evolving military requirements.
- Assess the designs in terms of network operations, DoD control, and cost and analyze the use of FSS, MSS, DBSS, and RDSS for warfighting.
- Apply new and emerging technologies.

8.2.1 Assessment of Design of Innovative Commercial Architecture

The design innovations used for the FSS architecture are multiple satellite vendors, tri-band terminals, and customer premise equipment (CPE). Multiple satellite systems provide a variety of transmission paths for each circuit from which an optimum performance path can be selected. Tri-band terminals were used to reduce the number of terminals or space required for terminals while still providing flexible communications. However, a complex network is created that requires interfacing among several commercial and military systems.

Customer premise equipment established communications directly at a user's location without requiring a communications infrastructure. In some cases, several CPE's were integrated into one terminal with short tail circuits to each user due to the close proximity of terminals. In other cases, user locations were assigned VSATs as CPE. To reduce the operations and maintenance cost for these locations a second, fully redundant VSAT with remote control options was installed.

These innovations customized the FSS architecture based on clearly defined requirements and provided optimum performance for a network. However, as requirements evolve, a custom design may not apply. In addition, operations and training may become a larger issues since complex systems and increased terminal variations are attributable to these innovations.

The MSS architecture design was innovative in the use of FSS to support special high data rate MSS requirements. Although this innovation clouds the ITU definition of MSS, it provides improved support to operationally difficult circuits. Other innovative MSS solutions depend on the outcome of the evolution of PCS systems.

8.2.2 Assessment of Commercial Systems Capabilities

The industry teams were unanimous in stating that the capabilities of commercial satellite communications systems could support all current and evolving general purpose requirements and selected core requirements (those not requiring anti-jam protection and moderate LPI/LPD requirements). A majority of core requirements could not be supported by systems available off-the-shelf in a cost effective manner.

No polar coverage was provided by current systems. With the advent of Mid and Low Earth Orbit satellite (MEO, LEO) constellations with highly inclined orbits, polar coverage may become available to support the limited number of general purpose users having a need to operate in this region.

Some FSS requirements could be supported easier and more cost efficiently on mobile satellite system while some MSS requirements could be supported easier and more cost efficiently on fixed satellite systems. Thus, the FSS and MSS terminology is becoming blurred as commercial satellite communications evolve to address the full range of user requirements.

Steerable Ku-band spot beam antennas on INTELSAT can support the throughput requirements of deployed GMF and shipboard Navy terminals. However, non DoD commercial demand for use of these antennas may eliminate this capability for the military. The need to reserve a large number (e.g., up to seven) of transponders to ensure uncontested use of the steerable spot beam and the possible compromise of operational security in steering the beams to cover the deployed forces may not be cost effective.

The use of remotely controlled, automatic switched, and redundant small terminals will reduce the additional number of personnel required for operations and maintenance. Depot and regional level maintenance will also reduce the need for on-site trained maintenance personnel.

Network control will be integrated with DISN operational control system. This consolidation provides enhanced flexibility in network configuration and allocation and control of resources. Commercial satellite TT&C will continue to be performed by the satellite operators.

8.2.3 Assessment of Design for Military

The assessment of the design for military usage looks at the vulnerabilities of a commercial system. Vulnerabilities such as interception, detection, geolocation, exploitation, and intentional jamming exist when using the commercial satellites. However, a few preventative measures could be used.

- Attempt to ensure that all available security measures (encryption and authentication) are used properly and continuously and that these measures remain independent of commercial signaling practices.

- Attempt to eliminate automatic responses (voice, terminal identification, or location) to radio inquiries.
- Continue to consider Iridium because, if the manufacturer's claims prove accurate, this system could be less susceptible to adversary actions.

8.2.4 Assessment of New Emerging Technologies

Of the new emerging technologies, four (ATM, CUPID, Network Interoperability and Transportable Gateways, PCS and Handheld Terminals) produce significant results for the CSCI program, because they introduced improved methods of supporting difficult or unique requirements. These technologies could have a strong impact on the CSCI program because they introduce the technology that can feasibly produce a wideband capability with rapid data transmission and good voice quality that will extend C4I into small (handheld) terminals in the tactical arena. One example is the use of ATM to deploy B-ISDN to JTF. Small handheld terminals will offer global services once a PCS system(s) is introduced. New systems will consist of COTS equipment and interface directly with fiber optic networks.

Four technologies that are important but have less of an impact are: Embedded Encryption, Multi-band Antennas, ACTS, and DBS. Embedded encryption, ACTS, and DBS will provide more secure communications via satellite. This security is achieved by encryption or by the use of spot beams or by the use of small receive terminals that are difficult to detect. Multi-band antennas and ACTs extend the availability of satellite communications by frequency reuse or the use of new frequency bands.

CHAPTER 9
CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The CSCI program defined what type of requirements are suitable for transition to commercial satellite service. These requirements are general purpose (no anti-jam and modest LPI/LPD) and located between 70° North to South. Low data rate requirements (32 kbps and below) can be supported on existing satellites such as INTELSAT, PanAmSat, Eutelsat, and INMARSAT for both fixed and mobile terminals. Medium data rate requirements for mobile terminals will become supportable by commercial satellites in the near to mid term, as technology advances. Medium and high data rate requirements for fixed terminals can be supported currently on existing satellites. High data rates for mobile terminals are not possible at L-band until PCS systems (Iridium, Globalstar, and Odyssey) have become operational. The MSS architecture depends on secondary uses of FSS frequencies for mobile high data rates. The feasibility of using this approach will be determined on a case by case application.

The CSCI program also verified that commercial satellites has sufficient capacity to support military requirements. Although exact numbers of transponders, satellites, and earth terminals needed to support future requirements must be determined, commercial satellites can support all current general purpose requirements and all projected growth in those requirements. Future requirements need to be identified to service providers several years in advance.

A prototype Network Planning System (NPS) was developed to assist DoD in planning, controlling and managing all military circuits that are transitioned onto commercial satellites. The NPS was developed along current DSCSOC capabilities but with variations due to commercial satellite nuances. The basic features of an enhanced NPS for DoD planners and operations personnel were clearly defined.

The CSCI program evaluated the vulnerabilities associated with commercial satellite communications. The threat postulated for the CSCI study has been accepted and adopted by members of the DoD satellite community.

The CSCI program developed a requirements document from the ISDB that is being used for National and International SHF studies. This document helped to clearly define the

boundaries of support by various satellite systems by providing a recognized and agreed upon set of requirements.

The CSCI program has provided the Government with a way to implement cost savings for satellite communications while still supporting the same level or an increased level of support in requirements. Cost savings were achieved by bundling currently leased circuits to obtain volume pricing discounts. Cost savings will also be achieved by reducing demand on research and development of additional military satellites to support requirements which might better be serviced by commercial satellites. Quantified cost savings for operations of military circuits on commercial satellites needs to be determined.

9.2 RECOMMENDATIONS FROM CONTRACTORS

A follow-on to this study was recommended to accomplish support for military links on commercial systems in the following areas:

- Initiate a Pilot Program to validate the private network concept and establish cost savings
- Obtain volume discount pricing for mobile satellite services (could be cost effective on long term leases)
- Begin Host Nation Approval Negotiations for pilot sites and contingency operations since approval time will vary from immediate to negotiations over years.

The main recommendation from this study is to resolve issues still at large by implementation of a pilot program. Figure 9-1is a notional representation of a Pilot Program.

The contractor's Implementation, Host Nation Approval Negotiations, Acquisition, Transition, and Logistics plans can be used as a guide to achieve a pilot or full scale commercial network capability.

Strategies for implementation are:

- Early commitment to leasing resources or purchasing the first right of refusal to guarantee availability of transponder resources.
- Show capabilities of commercial FSS satellites to provide backhaul of MSS maritime high data rate services with a pre-operational demonstration.
- Compete new systems as they begin operations to allow the government flexibility.

- Compete for new services as commercial systems evolve to expedite development of a private network.

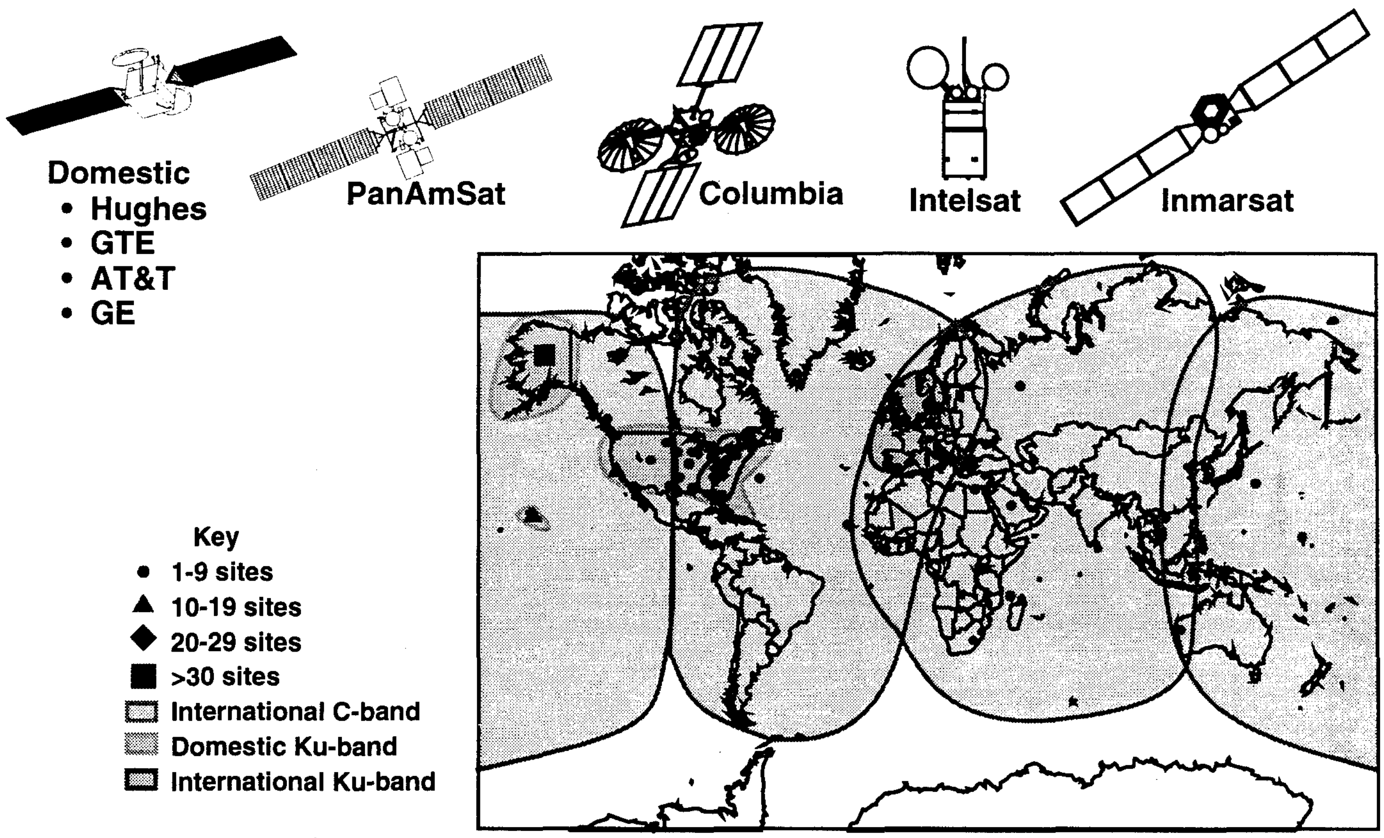


Figure 9-1. Pilot Network Coverage Area

Strategies for Host Nation Approval Negotiations are:

- The negotiations should be conducted by the U.S. commercial service integrator and the foreign telecommunications entity. The service provider will obtain the license and be responsible for meeting domestic and international regulatory requirements.

- The U.S. Government needs to negotiate agreements with host nations only when it plans to operate a station in that country, or bypass the local telephone company.

The contractor's strategy for acquisition of equipment is:

- Gather vendor information, develop site configurations on a regional basis, and prepare documentation of plans ready for Government approval.

- Design similar sites to a standardized configuration.
- Use centralized planning and bulk purchases to decrease cost.

Strategies for transitioning circuits from military to commercial satellites are as shown in Figure 9-2 and can be accomplished by the following actions:

- Initiate transition for point-to-point maritime, aeronautical, and land mobile satellite secure voice and data service immediately by transitioning the smaller (more easily transitioned) networks first.
- Implement communications links according to region, service type, and priority as defined by the proposed CSCI Program Office.
- Provide all networks with dual paths while the new network is being established (providing seamless operations).

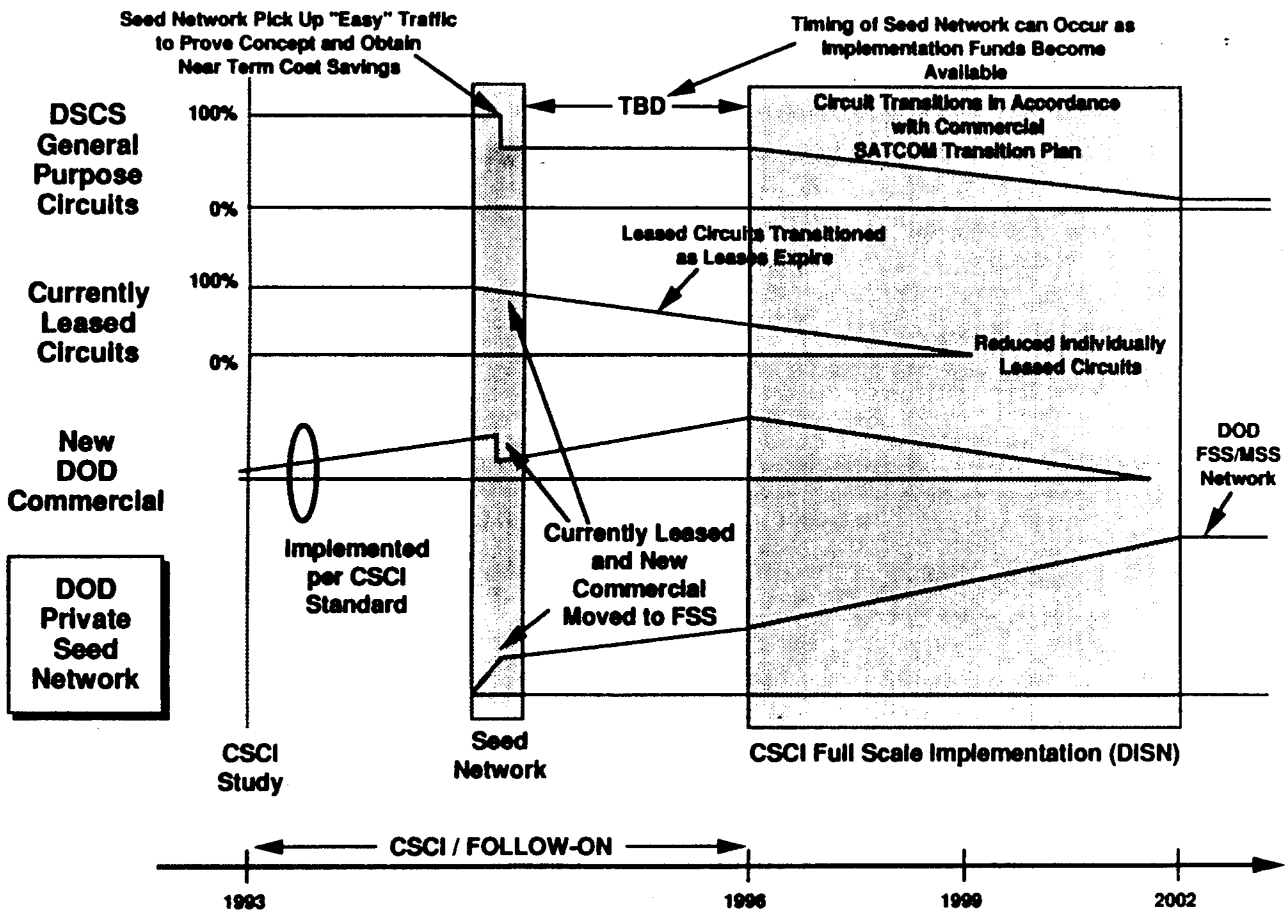


Figure 9-2. Commercial SATCOM Transition Plan

- Construct an interconnect facility (ICF) between the military and commercial gateways.
- After 2002, establish the Government private network based on available commercial MSS suppliers and the possibility of interoperation among systems.

The contractor's recommendations for Logistics is:

- All critical components except antennas will be redundant on FSS system.
- All critical components including antennas will be redundant on VSATs.
- VSAT terminals will have remote control or automatic switchover.
- Regional repair personnel instead of on-site operators and maintenance personnel will be used at VSAT terminals.

9.3 OVERALL OBSERVATIONS

The industry helped the DoD to broaden its application of current and future commercial satellites. The industry's recommendations were sound and can be adopted to meet many of the DoD's general purpose, unprotected requirements. The demonstrations served to show the operational utility and innovative ways of using commercial satellites. The CSCI study contractors achieved the goals of analyzing long-term DoD communications needs and determining to what degree and how those needs could be met by current and projected commercial systems. The study teams led by COMSAT Corporation, Hughes Aircraft Co., and Space Systems/Loral performed in an outstanding manner.

APPENDIX A

LIST OF ACRONYMS

ACTS	Advanced Communications Technology Satellite
ATO	Air Tasking Order
AJ	Anti-Jamming
ACOC	Area Communications and Operations Centers
ATM	Asynchronous Transfer Mode
AGC	Automatic Gain Control
B-ISDN	Broadband-Integrated Services Digital Network
CDMA	Code Division Multiple Access
CSCI	Commercial Satellite Communications Initiative
CUPID	Compact User Position Intelligence Dissemination
COTS	Commercial-off-the-Shelf
CPE	Customer Premise Equipment
DISA	Defense Information Systems Agency
DAMA	Demand Assigned Multiple Access
DoD	Department of Defense
DBS	Direct Broadcast Services
DBSS	Direct Broadcast Satellite Services
DISN	Defense Information Systems Network
DOCS	
DIMS	Defense Integrated Management System
FDDI	
FSS	Fixed Satellite Systems
GEO	Geosynchronous Earth Orbit
GPS	Global Positioning Services
HAC	House Appropriations Committee
INMARSAT	International Maritime Satellite
ISDB	Integrated SATCOM Database
INTELSAT	Integrated Satellite
ICF	Interconnect Facility
ISO	International Standards Organization
ITU	International Telecommunications Union
JCSC	Joint Communications Satellite Center
JOSC	Joint Operations Support Center
LES	Land Earth Station
LEO	Low Earth Orbit
LPI/D	Low Probability of Interception and Detection
MEO	Medium Earth Orbit
MILSATCOM	Military Satellite Communication
MilitaryOC	military Operations Centers
MSS	Mobile Satellite Systems

NCA	National Command Authority
NCS	Net Control Subsystem
NC	Network Control
NCT	Network Control Terminal
NMS	Network Management System
NMC	Network Monitoring Center
NOC	Network Operations Center
PCS	Personal Communications System
PSTN	Public Switched Telephone Networks
QPSK	Quaderature Phase Shift Keying
QAM	Quaternary Amplitude Modulation
RDSS	Radio Determination Satellite Service
RSSC	
SATCOM	Satellite Communications
SC	Satellite Control Network
SCPC	Single Channel Per Carrier
SONET	Synchronous Optical Network
TCOC	Technical Control and Operations Center
TC	Terminal Control
VSAT	Very Small Aperture Terminals

APPENDIX B
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